Renewable Energy Academic Partnerships (REAP)

Arizona State University
Tempe, Arizona
August 5 – 9, 2003

REAP 2002

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Arizona State University
Tempe, AZ

Arizona State University is one of the premier metropolitan public research universities in the nation. Enrolling more than 50,000 undergraduate, graduate, and professional students on three campuses in metropolitan Phoenix, ASU maintains a tradition of academic excellence in core disciplines, and has become an important global center for innovative interdisciplinary teaching and research. ASU offers outstanding resources for study and research, including libraries and museums with important collections, studios and performing arts spaces for creative endeavor, and unsurpassed state-of-the-art scientific and technological laboratories and research facilities.

In addition to the historic main campus in Tempe, a college town in the midst of a dynamic metropolitan region, the university comprises two newer campuses with more specialized missions: ASU West, in northwest Phoenix adjacent to Glendale, and ASU East, a polytechnic college, in Mesa. In downtown Phoenix, ASU's Extended Campus offers academic programs and professional certificate programs.

ASU is research-driven but focused on learning—teaching is carried out in a context that encourages the creation of new knowledge. The faculty includes recipients of prestigious academic and professional awards, including membership in the national academies. ASU currently ranks sixth among public universities in its enrollment of freshmen merit scholars. The university champions diversity, and is international in scope, welcoming students from all 50 states and nations across the globe. ASU is an active partner with the private sector in initiatives to enhance the social well-being, economic competitiveness, cultural depth, and quality of life of metropolitan Phoenix and the state.

New Solar Technology Designed to Compete with Conventional Energy

Pamela Ryan, First Solar

On June 25, at ASU East's internationally known Photovoltaic Testing Laboratory (PTL), First Solar "flipped the switch" on a uniquely designed 30-kilowatt solar array connecting First Solar's breakthrough technology to the Salt River Project grid.

ASU East's Photovoltaic Laboratory is one of three in the world certified to evaluate the performance, reliability and durability of "photovoltaic modules," that is, solar panel components that convert sunlight into electricity. It is the only such laboratory in the United States. ASU East PTL Director Govindasamy Tamizhmani said if all goes well over the initial three-year testing period, he expects the experimental solar facility to provide fully half the electrical requirements of the Photovoltaic Laboratory-an energy savings equivalent to that consumed by eight average Arizona homes.

First Solar, with an office in Scottsdale Arizona and a state-of-the art manufacturing facility outside of Toledo, Ohio, selected the site at ASU East for this test array because of its reputation in the solar industry. "We are interested in ongoing testing of our breakthrough technology at an accredited solar laboratory, and PTL is ideal for our purpose," says Wayne Monie, vice president at First Solar. "PTL will provide First Solar independent field evaluation and validation of our current technology and of future improvements we make to the product."

The First Solar experimental solar facility includes 600 solar modules in panels oriented flat-on-the-ground, and covering approximately 4,600 square feet in the Photovoltaic Laboratory testing yard. Because Arizona has fewer cloudy days than any other state, it is an ideal solar module testing location, and ASU faculty and students have developed a variety of outdoor testing programs and indoor weather chambers to test modules under typical long-term outdoor conditions as well as conditions of extreme heat, cold, humidity and weather anomalies such as wind and hail storms.

According to PTL Manager Liang Ji, "A data acquisition system relays continuous up-to-the-second performance information not only to ASU East researchers, but to the product development team at First Solar in Toledo, Ohio."

"As conventional energy becomes more scarce and expensive, photovoltaics becomes more cost effective as a power source," says Tamizhmani. "In the bargain, solar energy significantly reduces greenhouse gas (CO2) pollution. Every kilowatt hour of electricity generated by solar modules reduces CO2 pollution by 1.5 pounds."

The First Solar experimental solar facility at ASU East is expected to generate 62,415 kilowatt hours of energy per year.

A manufacturer of thin film photovoltaic (PV) modules, First Solar is the first to develop breakthrough technology and patented production processes capable of producing high volumes of solar modules at costs approaching conventional energy cost levels. First Solar's process integrates novel semiconductor coating methods and device architecture with automated, high throughput manufacturing methods - a new paradigm in the solar industry. First Solar's initial factory and technology center are located in Perrysburg, Ohio, and its corporate and marketing office is in Scottsdale, Arizona.

U.S. Department of Energy's (DOE)
National Renewable Energy Laboratory (NREL)
Renewable Energy Academic Partnership (REAP) Review Meeting

Fourth Annual Program Review Meeting and the
DOE-NREL Minority University Research Associates (MURA)
Program for Solar Technology
(formerly, "DOE-NREL HBCU-PV Research Associates Program")

Arizona State University
University Drive and Mill Avenue
Tempe, AZ

August 5 – 9, 2003

Tuesday, August 5, 2003
Arizona State University, Memorial Union Building, Turquoise Room, 208

8:30 – 9:30 a.m.	***Registration and Continental Breakfast*** (Late Visual Presentation Submission on CDs/zip disks, poster set-up)
9:30 –10:25 a.m.	***Opening Ceremony*** Moderator, Mr. Kevin Johnson, MURA Research Associate
9:30 a.m.	***Welcome to Arizona State University & Acknowledgments*** Dr. Albert McHenry, Dean, College of Technology and Applied Sciences, ASU East
9:40 a.m.	***Welcome to REAP 2003*** Dr. Robert McConnell, PV Exploratory Research Project Leader, National Center for Photovoltaics, NREL
9:45 a.m.	***DOE/NREL HBCU Photovoltaics (PV) Research Associates Program /Presentation of Faculty*** Fannie Posey Eddy, NREL – MURA Project Leader
9:55 a.m.	***ASU East Alternative Energy Technology Program*** Dr. G. Tamizh-Mani, Director, Photovoltaic Testing Laboratory Arizona State University East

10:10 a.m.	***Break***
10:15 – 11:45 a.m.	***Symposium: Strengthening Minority Serving Institutions (MSIs) and Preparing Students for Roles in Renewable Energy Technology Research and Leadership*** ***Speaker/Moderator: Frank Stewart*** ***"Center for Energy Research and Technology"*** Dr. Harmohindar Singh, Director, College of Engineering North Carolina A & T University ***"Opportunities for Research and Study at the Florida Solar Energy Center"*** Dr. Carol L. Emrich, Principal Research Engineer, Florida Solar Energy Center
11:45 a.m.	***Break***
12:00– 1:00 p.m.	***Luncheon*** Moderator, Mr. Chinua Mosley, MURA Research Associate ***Guest Speaker*** Charles E. Backus, Provost, Arizona State University East Campus
1:00 p.m.	***Break***
1:10 - 5:30 p.m.	***Technical Presentations and Poster Session*** Moderator, Ms. Kara Broussard, MURA Research Associate
1:10 p.m.	***"Meeting R&D Challenges of Si-PV Industry: Some NREL Contributions,"*** Dr. Bhushan Sopori, NREL Ms. Kenyatta Williams, Southern University
2:00 – 3:45 p.m.	**<u>North Carolina Central University</u>** **Department of Physics, North Carolina Central University, Durham, NC** Dr. J. M. Dutta (PI): ***" Investigation of Photovoltaic and Thermophotovoltaic Semiconductors (program review)*** ***"Residual Stresses and Electronic Properties in multi-layer thin films and quantum dots,"*** K. Wang, B. Vlahovic, V. Suslov, I. Filikian, J. Dutta ***"Characterization of Conducting Polymer for Solar Cells Application,"*** A. Holly[1], S. S. Mammana[2], V. Borjanovic[1], B. Vlahovic[1] and J. M. Dutta[1] ***"Residual Stresses Modeling In Thin Films and Quantum Dots,"*** Darek Woods Faculty Advisors: Dr. Kai Wang, Dr. J. Dutta and Dr. Branislav Vlahovic

	"Efficiency of Solar Flat-Plate Collectors for Durham, NC Area," Doryne Sunda-Meya, U. Udoko, A. Barnett, and G. Vlahovic
	"Recrystallization of a-Si:H by Laser Beams," Justice McConnell, J. Dutta, and B. Vlahovic
	"Design and Construction of the Chamber Thin Films and Quantum Dots Fabrication," B. Vlahovic
3:45 p.m.	***Break***
4:00 – 4:30 p.m.	**Howard University**
	"Optimal Power Dispatch of a PV System with Gaussian Distributed Power," Robert Sowah
4:30 p.m.	**North Carolina Agricultural & Technical State University** ***"Optimizing Manufactured Housing Energy Use,"*** Alaina Jones
4:30 p.m.	***Break***
4:45 p.m. **(University Club)**	***Reception and Poster Session in the University Club*** - (for Howard University, North Carolina A&T University, and North Carolina Central University presenters)

Wednesday, August 6, 2003
Arizona State University, Memorial Union Building, Turquoise Room, 208

8:30 a.m.	***Continental Breakfast***
9:00 – 12:35 p.m.	***Continue Technical Presentations*** – Moderated by Karla Horton, MURA Research Associate
9:00 a.m.	**Arizona State University** ***"Remote Weather Data Acquisition System,"*** Sumanth Lokananth
	"Preliminary Report on Energy Rating of Photovoltaic Modules Using Natural Sunlight," Yingtang Tang
	"Fuel Cell Based UPS System for a Desktop Computer," James Gonzales
	"Field Performance of Amorphous Silicon Modules in Desert Climatic Conditions," Vijay Srinivasan Lakshman
10:00 a.m.	**Hampton University** ***"The Floating Theater,"*** Michael Brown

10:30 a.m.	<u>**Central State University**</u> ***"The Central State University Renewable Energy Research Associates Program-An Overview,"*** Clark Fuller, PI ***"Solar Water Heater as Pyranometer/REEP Summer Internship,"*** Tehron Jones, Student Research Associate ***"Effect of Electron Beam Radiation on Solar Cell," Kent State University Summer Internship,"*** by Jessica Newton, Student Research Associate ***"African Solar Village Outreach Program,"*** Qadwi Bey, CARET Renewable Energy Consultant
11:30 a.m.	<u>**Southern University**</u> ***"Status of the NREL-PV- Project at SUBR,"*** Rambabu Bobba, Principle Investigator ***"Carbon Nanotubes for Hydrogen Energy Storage,"*** Daryl Shepherd ***"Hybrid Power Sources,"*** Diletha Kemp, Electrical Engineering ***"Photoelectrochemical Production of Hydrogen,"*** A. Farrah, Chemistry and Physics
12:35 p.m.	***Lunch with Guest Speaker***
12:35 – 2:00 p.m.	Moderator, Kara Broussard, MURA Research Associate ***Guest Speaker*** – Dr. Larry Kazmerski, Director, National Center for Photovoltaics, NREL
2:00 p.m.	Break
2:10 – 3:45 p.m.	Technical Sessions – Moderator, Ms. Kenyatta Williams, MURA Research Associate <u>***Developing Careers in Renewable Energy** **Symposium***</u> ***Guest Speaker and Moderator –*** James M. Posey, General Manager, Municipal Light & Power, Anchorage, Alaska Alen Chang, Applications Marketing Engineer United Solar Ovonic, Auburn Hills, MI Rahsaan Arscott, Energy Systems Specialist University of Texas Health Science Center at Houston, Facility Operations - Energy and Engineering Services Houston, TX Oral LaFleur, Technical Director Living Systems Limited and Collaborator, Texas Southern University, and College of The Bahamas Renewable Energy Program

3:45-5:00 pm	***NREL MURA Internship Program Presentations***
	Karla Horton, Southern University**, *"Biomass Research and Development Control Design Engineering"***
	Kevin Johnson, Florida A&M University, ***"Working with The FEMP Technical Assistance Team"***
	Kara Broussard, Southern University, ***"Solar Photovoltaic Hydrogen"***
	Doryne Sunda-Meya, North Carolina Central University, ***"Rapid Thermal Processing For Inkjet-Printed Ag Contacts to Si Solar Cells,"***
	Chinua Mosley, Clark Atlanta University, ***"Generating an AFM Simulator"***
5:00 – 6:00 p.m. **(University Club)**	***Reception and Poster Session*** (Southern University, Central State University, Arizona State University and NREL Interns)

Thursday, August 7, 2003
Arizona State University, Memorial Union Building, Turquoise Room, 208

8:15 a.m.	***Continental Breakfast***
	Technical Presentations - Doryne Sunda-Meya, MURA Research Associate, Moderator
8:30 – 10:00 a.m.	**Clark Atlanta University**, Dr. Gerald Grams, PI
	"Multi-year study of cloudiness in Georgia with implications for solar energy production," Mandock, Randal N. L, A. P. Chen, S. D. Fischer, G. W. Grams, G. Hoogenboom
	"Use of the CAU multiple-wavelength sun photometer to obtain measurements of total atmospheric extinction due to atmospheric aerosols, water vapor, and ozone," Dorsey, J. Lamar, R. L. N. Mandock, G. W. Grams, M L. Blyler, and S. D. Fischer
	"Comparisons between atmospheric extinction data obtained by the CAU multiple-wavelength sun photometer and the Micotops II sun photometer," Long, Cleon, G. W. Grams, R. L. N. Mandock, S. D. Fischer, and M. L. Blyler
	"Multi-year study of solar energy availability in Georgia," Johnson, Davall, R. L. N. Mandock, S. D. Fischer, and G. Hoogenboom
	"Performance of Concentrator PV Trackers," Irune, Ovuekoghene

10:00 – 11:15 a.m.	**Texas Southern University**, Science and Technology Research Center Houston Texas Dr. Allen Mitchell, Dean Ms. Joyce Lattimore, Research Coordinator
	"Urban Renewable Energy in addressing The International Energy Conservation Code, as well as, Compliance Analysis and Verification," Nkenge Mtendaji
	"The Urban Community," Tony Prince
	"Community Energy Distribution: Current Power and Lighting," Julie Bush, PV Research Associate
	"Community Limitation on Renewable Energy Forms," Tehron Jones
	"Guidelines for Applying Renewables in Urban Communities," Stern Sabaroche
11:15 – 11:45 pm.	**Fisk University** ***"Semiconductor Quantum Dot Based Solar Cells,"*** Richard Mu
11:45 a.m.	***Break***
12:00 – 1:45 p.m.	**Lunch with Speaker**, ***Chinua Mosley, MURA Research Associate, Moderator***
	Guest Speaker **– Taft Mohair, Executive, K3T Associates**
1:45 – 1:50 p.m.	***Break***
1:50 – 5:50 p.m.	**Arizona State University,** ***Dr. G. Tamish-Mani, Director, Photovoltaic Testing Laboratory***
	Short Course on Photovoltaics and Fuel Cells
5:50 p.m.	*Travel back to Hotel*
6:30 – 7:00 p.m.	***Poster Reception*** *(by Clark Atlanta University and Texas Southern University)*
7:00 – 8:30 p.m. **University Club**	**REAP Awards Dinner**
	Moderator, Mrs. Syl Morgan-Smith, NREL
	Awards Presentation – Fannie Posey Eddy, NREL and Syl Morgan-Smith, NREL
	Response from REAP Participants

Introduction of Guest Speaker by Jessica Newton, MURA Research Associate

Keynote Address by Dr. Stefanie Adams, Interim Associate Dean, Office of Graduate Studies and an Assistant Professor of Industrial and Management Systems Engineering, University of Nebraska, Lincoln

Friday, August 8, 2003

8:30 – 9:30 a.m.	APS Solar Test and Research (STAR) Center Tour
9:30 – 10:15 a.m.	Travel to ASU East Campus for Photovoltaic Testing Laboratory Tour
10:15 – 11:00 a.m.	ASU Photovoltaic Testing Laboratory Tour
11:00 – 12:30 p.m.	Photovoltaics and Fuel Cells Laboratory Practical
12:30 – 1:00 p.m.	Lunch/Workshop Summary/Conference Evaluation Forms
1:00 – 4:30 p.m.	Practicals for Break-out Groups, (casual dress for outdoor experiments) MEA – Fabrication of Membrane Electrode Assembly for Fuel Cells (Lilu Zhang) FC Testing – Observation of Fuel Cell Testing (Mani) IV – Outdoor measurement of current (I) and voltage (V) curve of a photovoltaic module (Liang)
4:30 – 5:15 p.m.	Travel Back to Hotel (Dinner on your own)

Saturday, August 9, 2003

9:00 – 10:30 a.m.	**Principle Investigator Breakfast Meeting (PIs Only) – Hotel Dining Room**
11:30 a.m.	**Check Out of Hotel**

Houston, Texas
August 2001

Conference Description

Program Overview

The DOE-NREL Minority University Research Associates Program (MURA) is an undergraduate research program that encourages minority students to pursue careers in science and technology. In this program undergraduate/graduate students perform renewable energy research projects during the academic year with principal investigators at their university and are awarded summer internships in industry or at national laboratories like NREL during the summer. Once accepted into the program students can work on a research project for 1-3 years. By providing renewable energy research opportunities, the program has proven to be very successful in retention of HBCU students in the science and technology areas and helping many students reach their educational and career goals.

Because of this program's successes, the program has been expanded to include additional minority-serving colleges and universities and all solar energy technologies. Each university will conduct research in 1-3 areas: Basic Research, Photovoltaic Panel Measurement and Testing and Solar Radiation Profile Study. This expansion will include Tribal Colleges-Universities, Hispanic, Alaska Native and Hawaiian Native serving college and university students to be included along with the Historically Black Colleges and Universities. Expansion to other solar energy technologies such as wind, bio-energy and geothermal, will provide additional solar energy project opportunities and internships. Students involved in research excel in the classroom learning experience and are committed to contribute to the development of renewable energy technologies in order to create a sustainable environment.

In the past six years the program has sponsored 70 undergraduate students' participation in research projects. In addition, more than 13,000 high school, middle school and elementary school students have benefited from renewable energy camps and summer academies. These activities have produced many research accomplishments and success stories. Several of our students have gone on to graduate school to master their skills in fields such as physics, chemistry, architecture and engineering. Others are now working in industry and government labs, using the knowledge and expertise they have gained as DOE-NREL Research Associates.

The impacts of this program in local and international communities occurred through student-managed community education projects, solar energy workshops and installations in South Africa, Senegal and even on the NREL campus. Each HBCU Team had different research projects and accomplishments. Perhaps the most valuable accomplishment has been the students' motivation to excel in their scientific quest for knowledge and to share their excitement of renewable energy with their local and international communities.

For 10 weeks during the summer students are given the opportunity to work with laboratory scientists and engineers as members of research teams at NREL or at another DOE national laboratory, university or industry partner. The program is intended to provide additional training and skill development needed to prepare students with the necessary education and experience that will enable them to pursue science and technology careers in the renewable energy fields.

At the close of the summer internship program Advisors, students and NREL professionals participate in an annual Renewable Energy Academic Partnership (REAP) review meeting and conference to discuss and share their research papers, future opportunities and the national and global role of renewable energy in ensuring a secure and sustainable environment.

The symposium will focus on NREL/DOE-funded projects at seven Historically Black Colleges and Universities and other Minority Serving Institutions, including Southern University and A&M College, Central State, Clark Atlanta, Hampton, Howard, North Carolina Central, and Texas Southern University. During the review of progress made on funded projects at each institution, undergraduates, advisors, and experts will have an opportunity to gather and discuss their research and future opportunities in the field of renewable energy. These review presentations will also provide valuable information about the role of renewable energy nationally and globally.

History

In 1995, the U.S. Department of Energy's (DOE) National Photovoltaics (PV) Program at the National Renewable Energy Laboratory, (NREL) in Golden, Colorado, funded nine Historically Black Colleges and Universities (HBCUs) for a period of three years, in an HBCU Photovoltaic Research Associates Program. The purpose of the program was to advance HBCU undergraduate knowledge of Photovoltaics, primarily through research investigations performed, and to encourage students to pursue careers in photovoltaics.

The universities selected were:

Southern University and A&M
Central State
Clark Atlanta
Hampton
Howard
Mississippi Valley State
North Carolina Central
Texas Southern University
Wilberforce University

Last Year

The DOE/NREL Renewable Energy Academic Partnership (REAP) Conference, which was established to review progress on the DOE/NREL funded projects at the nine HBCUs, was hosted by Howard University, Washington D.C., August 2002. The symposium focused on NREL/DOE-funded projects at the historically black colleges including progress made on funded projects as well as discussions about future opportunities in renewable energy.

This Year

The conference and review meeting is being hosted at Arizona State University in Tempe, AZ. Attendees will share their presentations, tour the ASU's research facilities and attend solar technology workshops. To further enrich their knowledge, professional and program development workshops are included. One workshop will focus on strengthening minority serving institutions and preparing students to excel in science and technology. In another, energy professionals and alumni from the DOE-NREL HBCU-PV Associates Program will talk about their professional life and work in the energy field. Finally, students and faculty will attend an eight-hour short course on "Photovoltaics and Fuel Cells" for which certificates will be awarded upon completion.

CARET

CARET works to promote educational opportunities in science and engineering for minority students through projects in renewable energy and sustainable development.

CARET is a partnership between minority universities, NASA, and OAI; dedicated to providing students with unique educational experiences in science through projects in renewable energy. This focus has created expertise in several areas of renewable energy; including numerous advanced research topics, technical design, sustainable development, and community outreach and education.

To learn more about CARET and their description for the REAP Program, please visit their website at: www.caret.org

Guest Speaker

Dr. Stephanie G. Adams
Interim Associate Dean, Office of Graduate Studies and an Assistant Professor of Industrial and Management Systems Engineering, University of Nebraska, Lincoln

Dr. Stephanie G. Adams is the Interim Associate Dean in the Office of Graduate Studies and an Assistant Professor of Industrial and Management Systems Engineering at the University of Nebraska-Lincoln. She received her Ph.D. in Interdisciplinary Engineering from Texas A&M University in August of 1998. Her areas of concentration were Industrial Engineering and Management. In 2003 she was named a National Science Foundation CAREER winner. Her research interests include Team Effectiveness, Collaborative and Active Learning, Engineering Education and Pedagogy, and Quality Control and Management. She has published a number of articles on the effective use of teams, as well as articles on issues related to mentoring students.

Dr. Adams is an honor graduate of North Carolina Agricultural and Technical State University, where she earned her BS in Mechanical Engineering, in 1989. In 1991 she was awarded the Master of Engineering degree in Systems Engineering from the University of Virginia.

Dr. Adams is a highly sought after speaker and workshop presenter. Most recently she delivered keynote addresses at the 3rd Annual McNair Undergraduate Research Forum in Jackson, MS, the 5th Annual McNair Program Luncheon in Buffalo, NY and TechSymposium 1999. She was also a workshop presenter at RISE 2001 and 2002, TechSymposium 2000 and the GEM Faculty Bridge Program. She is frequently called upon to present workshops for pre-college and collage age students. She has published a number of articles on the effective use of teams, as well as articles on issues related to graduate school and mentoring.

Previously, Dr. Adams served as the Director of the Advocates for Minority Engineering Student Success Program at North Carolina State University and the Minority Engineering Program Director at Texas Tech University. She also served as a Recruiter for National Consortium for Graduate Degrees for Minorities in Engineering and Science, Inc. (GEM), at the University of Notre Dame. As an undergraduate and graduate student Dr. Adams interned with the 3M Corporation in Minnesota, New Jersey and California.

Dr. Adams is the recipient of numerous awards. In 2001 she was selected as a Honorary member of Mortar Board; a recipient of the Star Mug Award, given by the Division of Student Affairs at the University of Nebraska, Lincoln; and awarded the Henry Y. Kleinkauf Outstanding Assistant Professor in Teaching Award. In 2002 she named as a Person Who Inspires by Mortar Board, November and she received the Service Award for Assistant Professors in the College of Engineering. Most recently she was awarded the 2003 Sue Tidball Award for Creative Humanity.

She is a member of the following organizations: Institute of Industrial Engineers (IIE); National Society of Black Engineers (NSBE); American Society of Engineering Educators (ASEE); American Society of Engineering Management (ASEM) and Delta Sigma Theta Sorority, Incorporated.

Her hobbies include listening to music, playing golf, traveling and watching women’s basketball.

Guest Speaker

Chien-Kai Alen Chang
Application Marketing Engineer, Unisolar

Uni-Solar: **Application Marketing Engineer**

- Commercial Photovoltaic Systems Date Acquisition System design.
- Commercial Photovoltaic Systems design.
- Supports the commercial division in project management and system engineering.

EDUCATION: **TEXAS SOUTHERN UNIVERSITY, Houston, Texas. Bachelor of Science Degree in Electronics Engineering Technology.**

EXPERIENCE: **University of Texas at Houston, Health Science Center. Houston Texas.**
Facility Energy Operation Electronic Associate Engineer

- Data analyze daily maintenance of building photovoltaic systems.
- Building HVAC project, digital control, and daily maintenance.

Photovoltaic Research and Demonstration Laboratory:
Texas Southern University, Houston, Texas.
Research Associate

- Tested and assembled battery free solar refrigerator and solar heat pump.
- **Participate in training for designing and building photovoltaic systems and daily maintenance of solar lab.**

GB Tech at NASA, Houston, Texas.
Research Assistant (Internship)

- Test and assemble in solar refrigerator and solar heat pump.
- Research parts, supplies, and equipment to determine most effective parts to be utilized.

PUBLICATION:

- "Battery Free Solar Refrigerator Project" Paper presented at the 2000 & 2001 National Renewable Energy Laboratory REAP Conference.
- 2000 TSU Graduate School Research Day-Battery Free Solar Refrigerator

AWARDS: National Renewable Energy Laboratory HBCU PV Research Associate Fellowship Award 1999, 2000, 2001.

Guest Speaker

Oral LaFleur
Technical Director, Living Systems Limited and Collaborator, College of The Bahamas & Texas Southern University Renewable Energy Program

Mr. Oral LaFleur has been involved in the Photovoltaic (PV) Industry since 1991. He spent many years as a builder of solar and navigational systems for automatic Power, Inc. His duties included inspecting parts for building solar and navigational systems, inspecting shop drawings for building these systems, completely assembling and wiring stand-alone solar and navigational systems according to specifications and preparing systems for testing and inspections.

In 1995, Mr. LaFleur was selected as the first National Renewable Energy Laboratory (NREL) Research Associate at Texas Southern University College of Science and Technology. As the NREL PV Research Associate, he investigated employment opportunities offered by the photovoltaics industries, determined and enumerated the education and skills needs for the full spectrum of employment including technology transfer, research in the PV industry. Along with the late Dr. Joshua Hill, Associate Dean, College of Science and Technology, Mr. LaFleur was commissioned by the National Renewable Energy Laboratory to visit South Africa. His mission was 1) to investigate and facilitate the renewable energy curriculum development work at Port Elizabeth Technikon in Port Elizabeth, South Africa; 2) identify potential shortcomings of their project and make recommendations to resolve these issues; and 3) to collect marketing and curriculum information for NREL.

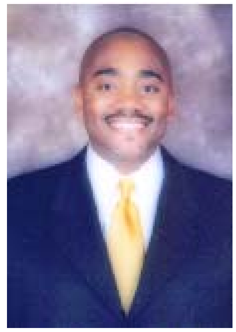
For six years, Mr. LaFleur served in the capacity as Project Director for the College of Science and Technology's Photovoltaic Research and Demonstration Laboratory and Program Manager for the Renewable Energy and Environmental Protection (REEP) Academy. In his position, Mr. LaFleur was responsible for overseeing the daily operations of the school's solar lab that used photovoltaic modules and related equipment for training in the generation of electricity. He also provided research support for the renewable energy program involved in the daily operation of the solar and wind energy systems, educational outreach, and dissemination of information. Mr. LaFleur supervised the solar lab personnel and the College of Science and Technology students selected as NREL PV Research Associates. He served on the board of directors for the Texas Solar Energy Society and president of the Houston Renewable Group (HREG) and a consultant to provide energy information to students, community organizations, teachers, businesses, etc. He now serves as a consultant for Texas Southern University College of Science and Technology renewable energy program.

His most recent appointment is with Living Systems Limited, a solar energy company based in Freeport Grand Bahama, where he serves as Technical Director and manager for the Nassau Office. In this position, Mr. LaFleur has the major responsibility for selecting products that the company carries. He participates in the training of all technical and sales staff and is responsible for designing major industrial and residential solar systems.

Mr. LaFleur received special training in Solar Radiation Instrumentation and Measurement from the National Renewable Energy Laboratory, Solar Energy Systems Installation and Design at Automatic Power and Texas Southern University and Passive Solar and Energy Efficiency through the Texas State Capital Energy Program. He earned his Bachelor of Science degree in Automated Manufacturing and his Master's degree in Industrial Technology from the College of Science and Technology, Texas Southern University.

Guest Speaker

Taft T. Mohair
President of Mohair Enterprises



Taft Mohair is a native of Houston, Texas and a graduate of Booker T. Washington High School for the Engineering Professions. While challenging himself through various activities at school and his place of worship, New Loyalty Baptist Church, Taft became aware of his God-given talent to lead others. His involvement in Booker T. Washington's National Society of Black Engineers (NSBE) Pre-College Initiative Chapter led Taft to serve as assistant chapter treasurer of the organization. Through his numerous activities as a student, Taft was able to hone his leadership skills as a scholar and team player.

After graduation, he enrolled in Prairie View A&M University's College of Engineering and Architecture (PVAMU CEA), where all of his skills were challenged and cultivated. It was during his educational experience at PVAMU that he took his active involvement with the National Society of Black Engineers (NSBE) to a higher level of commitment. As a result of his unwavering focus on excelling in his chosen career path, Taft went on to hold several positions within the organization: Cultural Studies Chairperson, Educational Programs Co–Chairperson, Academic Excellence Chairperson, Chapter Vice Chair, and Regional Professional Development Chairperson. The training and development he received in NSBE and as an INROADS intern positioned Taft for several opportunities. He was later selected as an intern for Motorola and United Gas Pipeline, and to perform undergraduate research in the Electrical and Environmental Laboratory at PVAMU.

After receiving a Bachelor of Science degree in Electrical Engineering from Prairie View A&M University in 1995, Taft accepted a position with Texas Instruments (TI) in Stafford, Texas. While at TI, he performed duties as a technical sales associate and marketing engineer in one of the company's Digital Signal Processing groups and the Micro controller Business Unit.

In 1997, Taft left corporate America to pursue his purpose in life: to change the social and economic condition of his global community. The strategies he has utilized to promote social and economic change have been focused mainly in the educational arena with the Houston Independent School District. He is a firm believer that if the condition of the community is to be changed, then the mindset of the community must be changed. Presently, Taft is a math and Algebra I teacher at Project Chrysalis Middle School. Concurrently, he devotes much of his time to building a global economic dynasty by focusing his energy on three entrepreneurial opportunities. These three businesses are the total global deregulation of public utilities and telecommunications, life skills development, and economic development. All of the businesses fall under the umbrella of Mohair Enterprises, of which he is the president. Taft has been asked to speak at numerous high schools, universities, non-profit organizations, business seminars, and churches. He continues to be sought after throughout the country.

Guest Speaker

James M. Posey, Esq.
General Manager, Municipal Light & Power, Anchorage, Alaska

In January 3, 2003, Jim Posey was appointed by Mayor George Wuerch as the General Manager for the Municipal Light & Power.

In 2000, Jim Posey was the Director of the Cultural & Recreational Services Department. In that position, he oversaw the Anchorage Museum of History and Art, the Anchorage Municipal Library System, Parks & Beautification, Sports & Recreation, and Chugiak/Eagle River Parks & Recreation. He managed a $20 million operation budget, 185 full-time and 140 part-time staff, $10 million of capital budget requests, as well as non-profit art and recreation program grants and various municipal boards and commissions.

Jim Posey was born and raised in Beaumont, Texas. After a stint in the Air Force, he attended Wichita State University, Wichita, Kansas, where he graduated in 1972. He then attended graduate school at the University of Kansas and received a Juris Doctorate degree in 1975.

He has worked as a Landman for ARCO in Dallas and he practiced law as an oil and gas Attorney for Worldwide Energy Corporation in Denver.

In 1979, ARCO Alaska Inc. asked him to return because of the big lease sale and unitization of the Kuparuk Field in Alaska, which was his special area of expertise. He has been in Alaska since that time. While at ARCO, he was a District Landman and Land Manager. He also served as a Resource Issues Manager, and Federal Government Relations Manager. He retired from ARCO in 1996.

He was the Building Safety Division Manager for the Municipality of Anchorage until Governor Tony Knowles appointed him to the Alaska Public Utilities Commission.

In his 18 years in the industry, he has been active in land acquisition, oil and gas leasing, U.S Corps of Engineers 404 Permitting, wetland advance identification, U.S. Fish and Wildlife mitigation policy, and local, state, and federal Coastal Zone Management. His published work relating to industry activities in wetland areas appeared in the January/February 1986 EPA Journal titled: WETLANDS AND OIL: COEXISTENCE ON THE TUNDRA.

Jim Posey has been a board member and past Chairman of Alaska Junior Achievement. He was a former board member of Anchorage Center for Families, which counsels and treats abused children and provides therapy for families. He is a founding member of the American Association of Blacks in Energy (AABE) and participates in the Urban League's BEEP Program. He is a member of the Academic Policy Committee "Family/Partnership Charter School".

Guest Speaker

Frank Stewart, Jr.
Chairman of the Board of Directors, Strategic Environment Project Pipeline (StEPP), Golden, Colorado

Frank M. Stewart, Jr. is the Chairman of the Board of Directors for the Strategic Environment Project Pipeline, (StEPP). (www.steppfoundation.org). He is also the former Manager of the U.S. Department of Energy (DOE) Golden Field Office. The office is responsible for promoting the development and commercialization of energy efficiency and renewable energy technologies by working with industry, for administering the management and operations contract for the National Renewable Energy Laboratory, and for providing administrative support to DOE's six Regional Support Offices.

Earlier, Mr. Stewart served as Deputy Assistant Secretary, Office of Technical and Financial Assistance, Office of Energy Efficiency and Renewable Energy, DOE. He directed grant programs and provided technical assistance for states and localities, including the Institutional Conservation Program, Weatherization Assistance Program, State Energy Conservation Program, Inventions and Innovation Program, and the Technical Assistance and International Market Support Activities for the Office of Energy Efficiency and Renewable Energy. He served there from 1990 until 1994. Mr. Stewart also served for a time as Acting Assistant Secretary of the Office of Energy Efficiency and Renewable Energy.

Mr. Stewart served as Associated Assistant Administrator for State Assistance Programs in the Federal Energy Administration (FEA), one of DOE's predecessor agencies, until DOE's formation in 1977.

Prior to the FEA assignment, he was with the Department of Health, Education and Welfare as the Assistant Executive Secretary for Education and Civil Rights (1975-1977). From 1966 to 1971, Mr. Stewart held teaching and administrative positions at Rutgers University and at Wesleyan University, Middletown, Connecticut. From 1963 to 1966, he taught school in East Orange, New Jersey.

In 1987, Mr. Stewart was the recipient of the annual Appreciation Award from the National Association of State Energy Officials. At the 1988 World Energy Engineering Congress, Mr. Stewart was named the Energy Executive of the Year. In 1994, the North Carolina A&T University School of Engineering honored him for his support of the school. He is also the recipient of the Department of Energy's Award for Exceptional Service and the Secretary of Energy's Gold Medal for Outstanding Leadership. Presently, he serves on a number of local, state, national and international advisory groups. He is listed in Who's Who in America and Who's Who in Science and Engineering.

In 1988, Mr. Stewart led the U.S. delegation to the University of Rome's World Conference on Energy Efficiency. In 1994 and 1995, he headed the U.S. technical delegations to Cote d'Ivoire, Botswana, and Ghana. Very recently he served as a member of Secretary O'Leary's historic missions to India and South Africa. From June 1994 until July 1995, Mr. Stewart was the principal energy staff person for the United States/South Africa Binational Commission. In 1996, he led the U.S. delegation that concluded the first Memorandum of Agreement between the United States and the nation of Uganda.

He received his bachelors and masters degrees from Wesleyan University in 1961 and 1963, respectively. He has done additional work at Harvard University and American University.

NREL

Meeting R&D Challenges of the Silicon Photovoltaics: Some NREL Contributions

Bhushan Sopori
National Renewable Energy Laboratory (NREL)
1617 Cole Blvd.
Golden, CO 80401

Abstract

The silicon photovoltaics (Si-PV) industry has grown very rapidly in the last few years to a production capacity of more than 450 MW/year. A continued growth requires that the cost of Si-PV production be reduced further. A major factor in PV energy production is the cost of Si solar cells. The PV industry has embarked on an approach that uses low-cost Si, which has high concentrations of impurities and defects, as the starting substrates for solar cells. Fabrication of high-efficiency cells on these materials requires mitigation of the effects of impurities and defects. During the last decade, research has led to methods that can getter impurities and passivate residual impurities and defects. Much of the work was developed under the DOE/NREL research program. Implementation of these techniques has resulted in commercial Si solar cells with efficiencies reaching 15%. As the industry grows further, newer R&D issues emerge. Two important areas that need R&D support are process development and process monitoring. Process development is needed primarily to advance the shift from single-step processes to those that accomplish several functions—helping to replace several process steps with a simple step. Significant success has been made in this direction. Of particular interest is well-developed impurity gettering into the formation of N/P junctions and Al contacts. Current research emphasis is in SiN processing, where SiN acts as an antireflection coating, a buffer layer through which the front contact is fired, and a source of hydrogen for passivation of residual impurities and defects. A brief review of the research aspects of this process will be given as an example. Process monitoring is another important aspect likely to help lower the production costs. In the past, the PV industry used many characterization techniques originally developed for the microelectronics industry. Many of these methods are not well suited for process monitoring/control of solar cell production. We will discuss NREL's research to develop two monitoring techniques for the PV industry.

Fuel Cell Based Uninterruptible Power Supply
For computers, and other applications

James Gonzales and Govindasamy TamizhMani
Fuel Cell Laboratory
Arizona State University East
7349 East Unity Avenue, Mesa, AZ 85212

Abstract

The foundation for fuel cell technology was discovered in 1839, but only recently has the fuel cell begun to find a viable outlet in commercial industry. More recently, fuel cell stacks (FCS) have been used to power a wide variety of applications, including buses and cars, portable electronic devices, and even large – and some smaller – stationary generating devices. One particular area of interest is to use a fuel cell for an uninterruptible power supply (UPS). Using a fuel cell to power a UPS has several benefits over the present widely available battery-powered UPS. A fuel cell powered UPS eliminates several problems traditionally associated with a battery-powered UPS, and therefore offers a superior alternative for highly critical power needs.

1. Background

Small UPS units traditionally use lead-acid batteries for the power source. The problem with batteries is that they offer limited run-time due to their limited capacity. In order to increase the run-time of a battery powered UPS, the number of batteries (or battery size) needs to be increased. This has led some UPS manufacturers to offer supplemental battery sources for a UPS, and even hot-swappable batteries. The problem with this is that the mass and size of batteries make it prohibitive for a UPS to power a system for any extended periods of time. Of course if power is unavailable, the batteries cannot be recharged while the power is down. Therefore, all available UPS power must be maintained in optimal condition until such backup power is needed.

For many batteries, this can be troublesome since over time, a typical lead-acid battery will lose power unless it is constantly monitored and recharged.

In order to address this deficiency, it was necessary to look for a source of power that would require considerably less volume than a battery, while providing the same (or more) available power for power critical systems, and then be readily available when it was needed. A fuel-based system would appear to be a viable and effective alternative to the battery powered UPS. A fuel-based system would permit continuous power during power outages as long as the required fuel was available. One of the premier choices available today would be to use a hydrogen fuel cell to power a UPS, instead of a battery.

2. Fuel cell stack instead of a battery

A proton exchange membrane (PEM) fuel cell system offers three distinct advantages over a battery powered UPS system.

1. As long as there is fuel available, the system will continue to operate during power outages.
2. As the fuel is depleted, the output power of the stack continues at full power.

3. The fuel of choice – hydrogen – can be stored for extended periods of time without self-discharge until needed by the UPS.

These three advantages offer the opportunity for a superior UPS system that can maintain system operations indefinitely. A PEM fuel cell is the fuel cell of choice since it operates quite well at room temperature, and does not require any "warm-up" time before operation. Other fuel cell types – a solid oxide fuel cell (SOFC) for instance – operate at very high temperatures (600°C to 1000°C), and require time to be brought up to operating temperature.

Hydrogen fuel for a FCS can be obtained from a natural gas supply line if a fuel reformer is available; resulting in maintaining critical system operations even when electrical power is unavailable for indefinite periods of time. This would be needed only under unusual circumstances since a few standard compressed gas hydrogen cylinders can run a computer system for a considerable time. This option may also be necessary if the number of critical systems – and therefore the power demand – is very high.

A simple fuel cell powered system was designed that was capable of powering a computer system for a considerable amount of time using a single hydrogen cylinder.

3. Design and operation of a fuel cell powered UPS.

The system was designed using four primary components.

1. An H-Power PEM250 fuel cell system. This is a PEM fuel cell system chosen for its portability and ease of use.

2. A Translectric, Inc. 300-watt, model 2412-25 DC-DC converter. Chosen for its wide input range of 20 to 60 volts, which is necessary for the wide output range – 20 to 40 volts – of the fuel cell stack. It has an output of a stable 13.75V needed for the inverter.

3. A Tripp Lite "automatic power system" inverter, model APS512. Chosen for its high efficiency, as well as its quality.

4. A computer, utilizing a Pentium II, 166MHz, with 32 MB of RAM, and a 4GB hard drive, along with a 15" Dell Trinitron® monitor. While somewhat archaic for a computer, it was sufficient for our purposes.

The system design layout is shown in Figure 1 below.

4. Results

The system was plugged into the utility power through the Tripp Lite inverter as shown in Figure 1, and all units were turned on. Due to the default of the automatic transfer switch, the PC was now being powered by the utility power (see Figure 2 below).

The utility power was then disconnected, and the Tripp Lite switched seamlessly to fuel cell backup power. The fuel cell system was able to pick up the load quickly enough for the computer system to remain on without failure. The fuel cell system was now the sole source of power for the computer (see Figure 3 below). After a short time the utility power was restored, and after the Tripp Lite inverter determined that full utility power had been restored (a process that takes about 15 seconds), it seamlessly restored the computer to utility power once again.

The utility power was removed once again in order to determine the approximate backup run-time for this UPS system using a single full "K" type, 2000psi standard cylinder of hydrogen containing about 196 ft^3 of hydrogen. The UPS was allowed to run continuously for several hours, and it was determined that a single hydrogen cylinder could supply enough fuel to this FCS to power a single PC between 35 and 45 hours. Further research allowing for the elimination of the DC-DC converter (the fuel cell system would directly power the inverter) would result in an even longer run-time due to an increase in system efficiency.

5. Conclusions

A typical battery-powered UPS would not have been able to provide continuous operation of the computer for as long as the FCS was able to provide without a considerable amount of battery power available. Furthermore, it would have been easy to integrate an additional cylinder tank of hydrogen into the system with an automatic switchover, thus doubling the run-time of the computer. However, it would be unusual for utility power to be down for more than 2 days.

The unit operated quite nicely, and opened the door for further possibilities of a multi-computer system (or other critical applications) powered by a single fuel cell system, or it may be better to use multiple fuel cell systems each with its own fuel source. Further research will need to be conducted to determine the optimal approach to a fuel cell powered UPS.

The primary restraint on a fuel cell powered UPS today is cost, since fuel cell systems are still quite expensive. However, that is expected to improve as fuel cell technology improves, and production volume of fuel cell systems increase. Since fuel cell technology is effectively in its infancy, so there is considerable potential for the further development of this “new” technology.

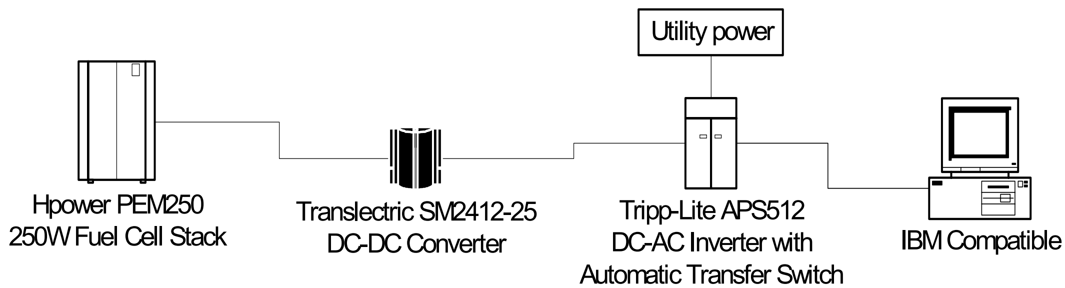


Figure #1: UPS System Design Layout

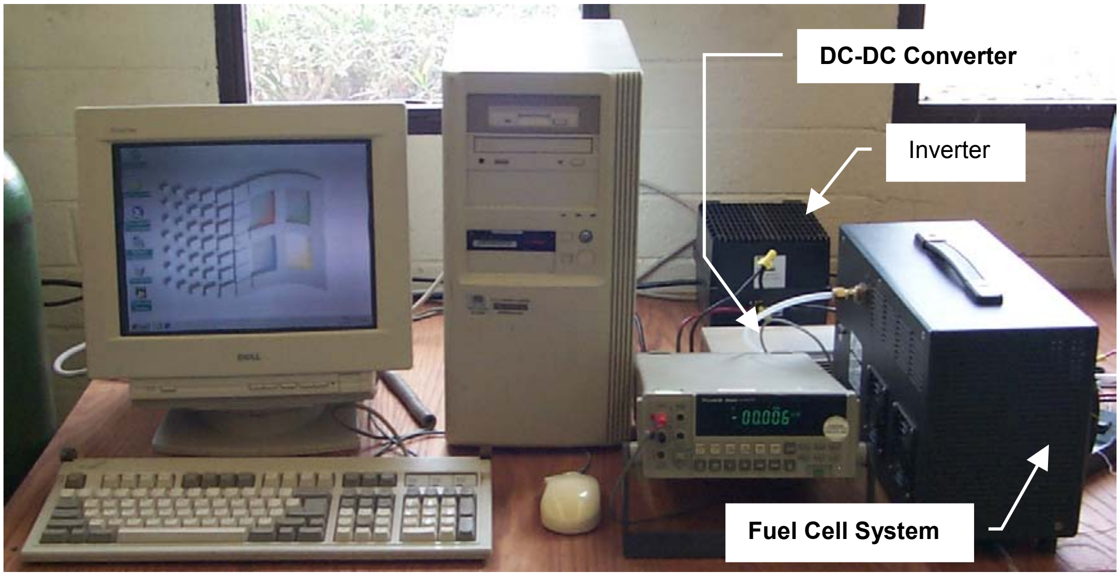


Figure 2: Photograph of a computer powered by utility grid – No current is flowing from the fuel cell stack. (Note that the DMM shows a voltage drop across the current shunt of -00.006mV. Since 100mV = 50A, this is equal to a negative 3µA or zero current).

Figure 3: Photograph of the computer powered by a fuel cell based UPS – current is now flowing from the fuel cell stack. (Note that the DMM now shows a voltage drop across the current shunt of +11.696mV. Since 100mV = 50A, this is equal to 5.848A of current being drawn from the fuel cell).

<u>**Acknowledgements**</u>

The financial support of ASU through its faculty-grant-in-aid (FGIA) program is greatly appreciated. This project was carried out using a fuel cell stack and a dc-dc converter generously donated by Arizona Public Service (Timothy McDonald) and Translectric, Inc., respectively.

PERFORMANCE OF a-SI MODULES IN DESERT CLIMATIC CONDITIONS

Vijay Lakshman, Todd Arends, Govindasamy TamizhMani
Arizona State University East
Photovoltaic Testing Laboratory
7349 E. Unity Avenue, Mesa, AZ 8521

Abstract

This paper focuses on the methodology for long term outdoor exposure testing and the performance of dual-junction amorphous silicon (a-Si) modules from two different manufacturers in desert climatic conditions. The performance of these modules appears to stabilize after about 1000 kWh/m^2 of exposure to sunlight in desert climatic conditions. The stabilized P_{max} of these modules experience a sinusoidal variation due to seasonal effects.

Introduction

Amorphous Silicon photovoltaic (PV) modules are commercially attractive because: they require minimum amount of semiconductor material for manufacturing; they are amenable to mass production methods; and have a low temperature coefficient resulting in lower power loss in summer as compared to crystalline silicon modules.

The performance of a-Si modules heavily depends on field conditions such as operating temperature, irradiance and spectral effects. This paper reports results obtained from 8 modules involving dual-junction a-Si technologies from two different manufacturers.

Installation and Data collection

Arizona State University Photovoltaic Testing Laboratory (ASU-PTL) is located at 33° 18' latitude, 111° 39' longitude and 405.4 m elevation above sea level. ASU-PTL has been conducting outdoor exposure testing and weather data collection for multiple clients since 1993.

There is no specific testing standard, or agreed upon approach to long-term exposure testing since the geographical location of the test dictates the exposure environment and this can fluctuate dramatically from site to site. In general, however, Arizona and Florida are the two exposure testing capitols due to these states' extreme average environmental testing conditions. Arizona experiences the least cloudy days (on average) of any other location in the U.S. and is a hot and dry climate. Florida, experiences much more cloud cover, and is a hot and humid environment.

The outdoor exposure testing and weather data collection follow the requirements of IEC 1646, Ed. 1 [1]. Modules are mounted outdoors at a fixed latitude tilt co-planar with irradiance detectors. Electrical performance data is collected on a regular basis. Wind speed and direction, rain, global and plane-of-array irradiance data are gathered and summarized for the total time the module is mounted outdoors.

The electrical performance evaluations are done as per ASTM E 1036M-96 [2], which addresses the investigation of PV module electrical performance, using natural sunlight, calibrated secondary reference cells, an IV curve tracer and various other weather data collection instruments. For comparison purposes, the data is translated to Standard Test Conditions (STC).

Data Analysis and Discussion

Typically hydrogenated a-Si thin films degrade on exposure to sunlight, which is more prominent during the initial stages of exposure and the degradation stabilizes after around 1000 kWh/m^2 of exposure to sunlight. The long-term degradation appears to experience a logarithmic decrease in P_{max} with a sinusoidal variation that can be attributed to seasonal effects [3].

Figure 1 shows the observed degradation of dual-junction a-Si modules with respect to number of days of long-term outdoor exposure. From the plot it is clear that the maximum degradation (15-20%) occurs during the initial stages. This light induced degradation is attributed to the Staebler-Wronski effect [4].

Figure 2 shows the effect of seasonal fluctuations in the STC performance of the outdoor exposure dual-junction a-Si modules. After the initial maximum degradation, the performance stabilizes and fluctuates depending on the season of the year. The STC performance is higher in summer than in the winter months. In the summer months, the decrease in efficiency is countered by thermal annealing, because of the high operating temperatures of the module [5].

In spite of the degradation observed, most of the modules continue to perform around their rated values even after 3-5 years of outdoor exposure.

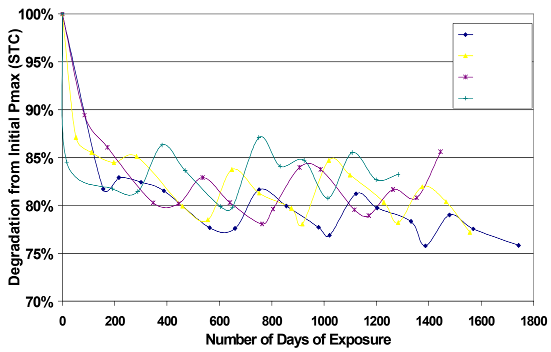


Fig. 1. Degradation of dual-junction a-Si modules [outdoor exposure started at different times of the year]

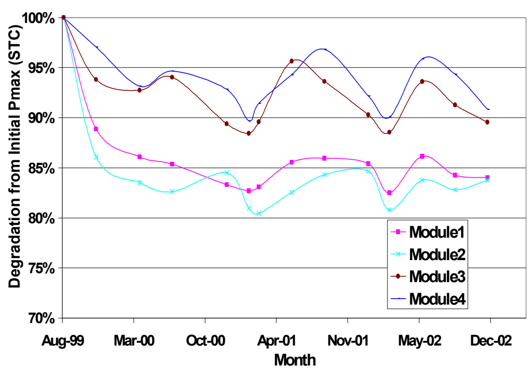


Fig 2. Seasonal variation of STC performance of dual-junction a-Si modules [outdoor exposure started at the same time of the year]

Conclusions

Eight dual-junction a-Si modules from two different manufacturers have been evaluated for their long-term outdoor performance. This study indicates that the performance of these modules stabilizes after about 1000 kWh/m^2 of insolation and sinusoidally fluctuates due to seasonal effects.

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REMOTE DATA ACQUISITION SYSTEMS:
A TINI based system for Photovoltaic weather data acquisition

Sumanth Lokanath, Bruce Millard, Liang Ji, Govindasamy TamizhMani
Department of Electronics &Computer Engineering Technology
Arizona State University East, 7349 E. Unity Avenue, Mesa, AZ

Abstract

The concept of applications, which operate independently and automatically with minimal human interaction, finds appeal in various areas ranging from the home to the far frontiers of space. One such area is the application of remote data acquisition systems. The data can be anything from the status of a light to the parameters of a complex system such as weather. This project has investigated a remote weather data acquisition system, which is low cost, user configurable, and has a generic framework to support extensibility. The solution uses the TINI, a Java based, programmable Internet enabled device connected to a network of environmental sensors to collect and transfer data to a remote server for storage and processing, using either a wired or a wireless interface. This system can autonomously and periodically transfer a comma separated value data file containing the weather data collected at specified intervals from the remote station to a remote server that can store and analyze this data. The work presented in this paper is an extract of an Applied Project report of one of the authors [1]

1. Background

In many regions, weather is very crucial in everyday activities and is closely monitored by both individuals and organizations. The current means of obtaining weather data by mass media such as television or radio is too generic as it covers vast geographical areas. It would be important for somebody who needs to monitor the weather to get information specific to his neighborhood. One such application is to collect weather data and module performance data at a remotely deployed Photovoltaic (PV) installation. Two kinds of data acquisition systems are commercially available, conventional 2-Wire systems and 1-Wire systems. Also the conventional 2-Wire remote data acquisition systems are more expensive compared to the 1-Wire systems. Currently available versions of 1-Wire weather systems use an onboard web server to serve data to clients via the Ethernet. However, these systems are constrained by lower memory limitations for storage of large amounts of data. Hence clients connecting to this TINI web server can view only limited data. This project aims to addresses these limitations by developing a low cost, autonomous java based, low footprint remote weather data acquisition system using readily and easily available equipment to collect and transfer local data to any PC equipped with an internet connection.

The 1-Wire sensors, as opposed to conventional 2-Wire systems use a single wire (plus ground) to accomplish both communication and power transmission. A single bus master (controller) can feed multiple slaves (sensors) over a single twisted-pair cable. An important aspect of this technology is that every slave has a globally unique digital address. 1-Wire technology has made possible the combination of electronic communication and instrumentation based on positive identification of individual nodes on a single self-powered net. Continued development of the technology has increased the array of 1-Wire chips able to interface with the environment, measuring events, voltage, current, temperature, position, etc. In turn, these chips enable the construction of sensors that measure a host of environmental parameters on a single twisted-pair cable [2].

2. Relationship between PV module performance and weather

Weather data consists of the collection of information, such as wind speed, wind direction, rainfall, ambient temperature, atmospheric pressure, relative humidity and irradiance of the sun. Major weather parameters that affect PV module performance/efficiency are solar irradiance, ambient temperature and wind speed. For PV modules, the output power and hence the energy generation decreases with an increase in module temperature. The module temperature is in turn a function of the incident irradiation, ambient temperature and wind speed [3]. Also, the efficiency of many commercial modules is lower at low irradiance levels than at high irradiance levels because of imperfections in the PV cells [4]. The performance monitoring of a PV system thus requires that the appropriate weather parameters be recorded.

3. Motivation and problem definition

Most conventional weather data acquisition systems collect data from the remote station and store the data in local storage. A technician manually (can also remotely when available) downloads the data from the internal memory of the data logger using proprietary or commercial interfaces onto a storage module and transfers the data to the main storage server. Some of the latest commercial systems also provide for Ethernet interfaces to upload the data to a remote server.

The disadvantage of such a data collection methodology is that it requires a person to monitor and periodically download the data. The system would be better off, if there was a way to automate this process end-to-end, between the weather station and the server. Secondly, the local storage on the data loggers is limited by the smaller memory constraint it imposes with respect to the main memory on the server.

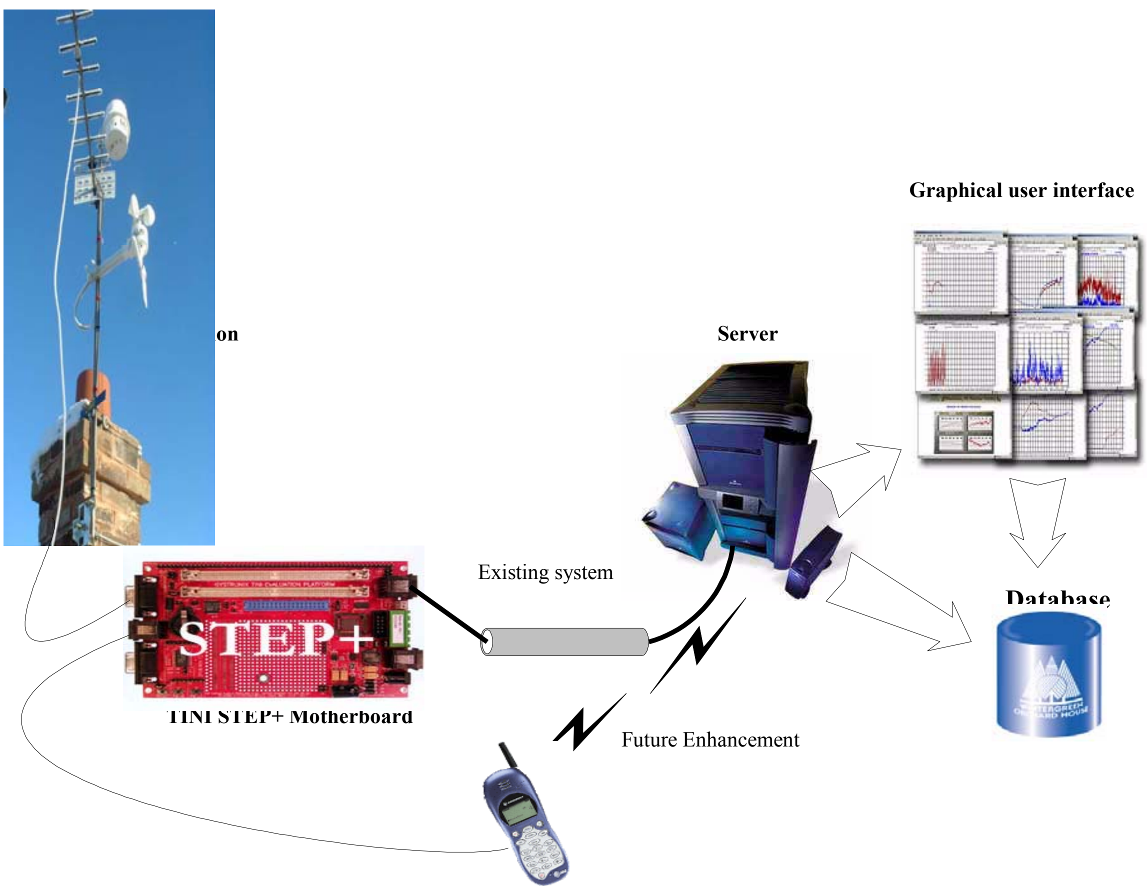

Figure 1: Graphical illustration of TINI based remote data acquisition system

Thirdly, the data logger is at risk of loosing whatever stored data there is available in the local memory, in situations such as a lightning strike to the weather station, if it is not built to be rugged. Lastly, most commercially available weather stations are only as extensible as the options the manufacturer provides.

There are many weather monitoring systems available in the market today. These systems tend to be expensive or are limited by the functionality of sensors that are provided to monitor the various weather parameters listed above. Also most products have their own proprietary interfaces or ways of displaying the output formats, which may not be the same as that required by the user. Any changes/additions would have to deal with trying to manipulate these proprietary interfaces and software. Thus, there arises the need to design a remote weather data acquisition system, which can be easily configured to meet the user's specific requirements and also one, which is more affordable.

4. Approach

The solution implements the weather station using the TINI – an embedded java based platform at the remote end to collect data from the various 1-Wire sensors mounted on the weather station. This collected data is formatted and transmitted to the base station for processing. Figure 1 above illustrates this.

The TINI uses the 1-Wire interface to collect data from the sensors and, on the other hand, it uses one of the user-selectable interfaces to transfer the data to the server. The user selectable interface can be either the TINI based wired Ethernet interface or the optional wireless packet data enabled iDEN phone.

When the wireless iDEN phone is used it is controlled by, a TINI based client module. The iDEN phone can transfer data wirelessly to the base station either by dialing out to a server or transmitting data as IP packets using the Over The Air (OTA) interface. The framework is flexible so as to allow the addition of more sensors or communication interfaces.

In a typical remote application, network availability to transfer data cannot be guaranteed to be always available and as such the application provides safeguards against such situations. The application uses a network polling mechanism when it needs to transfer data. When the network is unavailable, the data is stored locally and is transmitted later when the network is back online. The server on receiving the data verifies it and acknowledges the client of proper receipt, and consequently may store it in a database for further processing. The software is implemented using the Java programming language and the framework provided by the respective platforms on the TINI and the iDEN phone.

5 Results

The primary objective of this project is to design and implement a weather data acquisition system that monitors and collects weather data automatically from a remote weather station and uploads the data to the server. The other desired design objectives are persistent data storage capability: end-to-end concurrency control of data, a flexible and easily extensible framework, and a robust architecture. The present implementation meets all of these functional and design objectives. The system has been successfully tested using the wired Ethernet interface on the TINI. For temporary network outages, the system recovers from any possible transmission errors and transmits all pending log files to the server once the network becomes available. For irrecoverable network outages, a log file is created every upload interval as long as the system is running and the memory is not depleted. Applications are not typically memory intensive and as such there is ample time before system memory gets depleted. It can be safely assumed that in such a situation, the system administrator will perform maintenance and restore the system before the memory is depleted.

The output log file is in the comma separated file format, with each line representing the data points acquired from each of the sensors at the indicated measurement interval. Each log file also includes a header to make the output more readable. An example with 4 data points collected at 3-minute intervals is given below.

StationID,YYYY/MM/DD,Time,Temp(°C),WndDir,WndSped(m/s)
85281PTL0001,2003/4/10,15:17:21,29.7, S ,0.0
85281PTL0001,2003/4/10,15:20:27,29.68,SW ,0.0590736381
85281PTL0001,2003/4/10,15:23:34,29.7, W ,0.229718536
85281PTL0001,2003/4/10,15:26:41,29.68,SW ,0.1247110217

6 Conclusions

On completion of this project a few important conclusions have been reached. The foremost being the suitability of the TINI platform for remote data logging applications. With its built in support for Ethernet connectivity, 1-Wire networking, CAN bus, general purpose I/O and serial interfaces, it is a formidable device when coupled with its small form factor, and ruggedness for application to similar outdoor applications. Its integration with the JVM and fast application development using JAVA API's when coupled with the low cost of the device easily translate to profitability both in terms of development, and deployment time and cost based marketability. The original aim of this project was to develop the application as a technology demonstrator and proof of concept for deployment in remote data acquisition system applications such as for the PV industry. In its present form, the application meets all design objectives with the exception of providing the iDEN phone wireless interface. With additional modifications and development to incorporate the wireless communication interface, it holds great promise as a feasible solution as a truly remote data acquisition system.

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A Preliminary Report on Energy Rating of Photovoltaic Modules Using Natural Sunlight

Yingtang Tang, Liang Ji and Govindasamy TamizhMani
Photovoltaic Testing Laboratory
Arizona State University East
7349 E. Unity Avenue, Mesa, AZ 85212

Abstract

This paper describes the energy rating of photovoltaic modules using natural sunlight at Photovoltaic Testing Laboratory, Arizona State University East. A literature search on the energy rating of photovoltaic modules was carried out. Advantages and challenges of using natural sunlight as the light source for energy rating are analyzed. A thermal test bed (TTB) has been designed and built to obtain a matrix of performance data at different temperatures and irradiances using natural sunlight and refrigeration system. The incident angle effect is entirely eliminated by mounting the TTB on a 2-axis tracker platform.

1. Background

The nameplates of commercial photovoltaic (PV) modules typically provide information on the STC (Standard Test Conditions -- 1000 W/m^2 perpendicular irradiance; 25^{o}C cell temperature; AM 1.5 Global spectrum) electrical performance parameters (maximum power, open-circuit voltage, short-circuit current, and voltage and current at maximum power point). Though STC nameplate rating is good for comparing the performance of different modules at fixed conditions, these conditions are very rarely encountered in the actual field. Users may be able to obtain the performance parameters at another set of climatic conditions using STC rating, temperature coefficients provided by the manufacturers and translations equations of ASTM E1036-96 [1], but the accuracy of the translated parameters strongly dependent on the translational range of temperature and irradiance.

The PV module energy rating method, proposed in the IEEE P1479 Draft [2] and IEC 61853 Draft [3], is a comprehensive procedure and it can improve the translation accuracy significantly. The procedure calls for a collection of I-V parameters over a range of module temperature and irradiance level. The recommended test range of temperature is 5 to 60°C and irradiance is 100 to 1000 W/m^2. Collection of I-V curves over these temperature and irradiance ranges will also allow the users/system designers/testing laboratories to calculate the energy production of PV modules for the proposed five reference days [2, 3] or for the user specific climatic conditions.

Working towards the ideal solution, NREL has collected I-V curves of various commercial PV modules at different temperature and irradiance conditions [4, 5]. These tests have been carried out indoors. To obtain the I-V matrix, NREL has utilized a SPIRE 240A solar simulator and a heating blanket located a few centimeters below the module. The irradiance level is changed, between 100 and 1000 W/m^2, using a few layers of vellum/drafting sheets (a near neutral density filter) and the temperature is changed, between 15 and 50^{o}C, by controlling power to the heating blanket.

This project, being funded by NREL, aims to obtain the I-V matrix over the IEEE/IEC proposed temperature and irradiance ranges using outdoor natural sunlight as light source.

2. Advantages with using natural sunlight

Using natural sunlight as a light source has several advantages:

i. Elimination of very expensive solar simulator cost;
ii. Nearly no temporal instability on clear days;
iii. A possible long enough light exposure and data collection time (important requirement for slow responding technologies such as Cadmium Telluride);
iv. Most importantly, high level of spatial light uniformity on the very large area modules.

3. Challenges to use natural sunlight

There are several challenges to obtain the I-V matrix under outdoor ambient conditions. These challenges include:

i. Reaching the proposed lowest temperature of 5°C for all the commercial modules irrespective of shape/size of the modules and of outdoor temperature conditions;
ii. Physical construction of a large size thermal bed and a 2-axis tracker to accommodate extra large size commercial modules;
iii. Maintaining a low temperature gradient (less than 2^{o}C) between the superstrate and substrate of the modules irrespective ambient temperature;
iv. Maintaining a high level of module temperature uniformity irrespective of ambient conditions including wind speed;
v. Quick opening of light shutter and acquiring I-V data to minimize cell heating during the I-V data acquisition;
vi. Stabilizing the module temperature within a reasonable time to avoid the influence of spectral change during course of entire I-V matrix data collection.

4. Project Objectives

The multi-fold objectives of this project are:

i. Design and build a thermal test bed (TTB) to obtain I-V data at different temperatures using natural sunlight;
ii. Eliminate the incidence angle effect by mounting the TTB on a 2-axis tracker;
iii. Change the irradiance level using natural density filters, and
iv. Account the spectral influence using matched reference cells or spectral radiometers.

5. Work Done

i. Thermal load calculation of the system
ii. Custom-built air-conditioning unit based on the thermal load requirement of the system
iii. Designed and built a thermal test bed
iv. Ordered and installed a two-axis solar tracker
v. Mounted the thermal test bed on the installed tracker platform

Figures 1, 2 and 3 show onsite pictures of the work that has been done for this project.

Figure 1: Front view of thermal test bed along with an AC unit

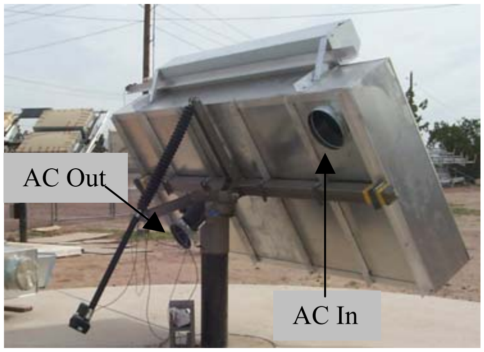

Figure 2: Rear view of thermal test bed and a 2-axis tracker

Figure 3: Thermal test bed with partially opened sliding-door

6. Planned Work

i. Procure commercial and developmental photovoltaic modules for the energy rating
ii. Obtain I-V matrix over a range of temperature and irradiance
iii. Correct spectral mismatch error, if any
iv. Inter-compare coefficients on identical modules tested outdoors at ASU and indoors at NREL
v. Predict energy production of tested modules per IEEE and IEC standards

Acknowledgement

National Renewable Energy Laboratory (NREL) funding support for this project is greatly appreciated.

Reference:

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PERFORMANCE OF CONCENTRATOR PV TRACKERS

Ovuekoghene Irune
Photovoltaic Testing Laboratory
Arizona State University East
7349 E. Unity Avenue, Mesa, AZ 85212

Clark Atlanta University
223 James P. Brawley Drive, S.W, Atlanta, GA, 30314

Abstract
As an intern student from Clark Atlanta University, my research work at the Arizona State University-Photovoltaic Testing Laboratory (ASU-PTL) for the summer of 2003 involves reviewing the solar tracker test standards (draft), contacting the industry to obtain performance and design specifications of solar trackers, reviewing the tracking systems and also to obtain scientific and trade literature on the concentrator PV trackers. The outcome of this research will help in providing information for the development of an International Electrotechnical Commission (IEC) standard for these concentrator PV trackers since there is currently no industry-wide defined standard available.

Introduction
Solar trackers are photovoltaic (PV) array support systems that track the sun in the daytime. The concentrator PV modules work only with DNI (direct normal irradiance) and if they are not facing the sun directly, the power output from the module will be zero or will not be at its maximum depending on the type of concentrator module. Because the earth is in constant motion, concentrator photovoltaic panels or modules hardly face the sun directly with incident angle less than 0.1^0. As a result of this a very low power is produced. The trackers help to adjust the concentrators PV modules in such a way that they are precisely aimed at the sun at all times. These concentrator PV trackers have been set up on the ASU-PTL site for testing and analysis to ensure that they work to produce the maximum power output. One of the solar sensors at ASU-PTL is not functioning as intended and my initial research work is directed to identify and rectify the root cause of this problem.

Method of tracking

1) Open loop and Closed loop tracking
Tracking systems can be either closed-loop or open-loop. Closed-loop trackers can behave in a manner that lacks consistency on cloudy days and require that the sensor head be accurately aligned with the sun. Night-stow, wind-stow and repositioning each day require additional attention. Open-loop systems rely on accurate clocks, complex computation, and the accurate operation of the mechanical units involved in the system. If these parameters drift, this leads to inaccurate pointing and a loss of power.

2) 1-axis and 2-axis tracking
There are basically two types of tracking structures; one-axis or single axis tracker, and two-axis or double axis tracker. The single axis tracker system turns on one axis following the sun from east to west. They are mainly used with flat-plate PV systems and some concentrator systems as well. The double axis tracker system, which is mainly used for PV concentrator system, tracks the sun's daily course (east-west) and also its seasonal course (north-south).

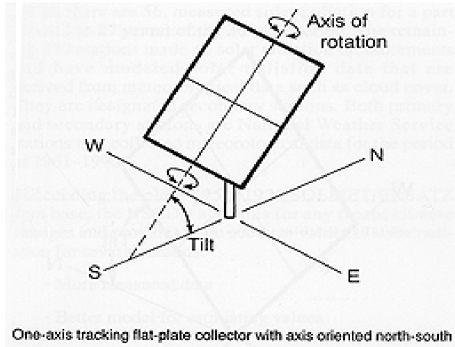

Figure 1: One axis flat plate collector.
(source: http://rredc.nrel.gov/solar/pubs/redbook/gifs/fig2.gif.)

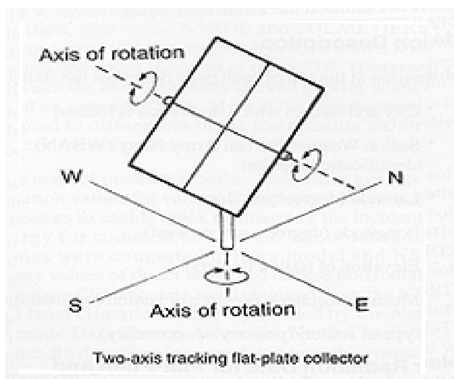

Figure 2:Two-axis flat plate collector
(source: http://rredc.nrel.gov/solar/pubs/redbook/gifs/fig3.gif)

3) Reporting on Initial work

This section presents the initial work done during this reporting period of the past three weeks. The solar trackers used in this research utilize a patented, closed loop, optical sensing system that sense the sun's position and are able to track it. The sensors mounted on the tracker are responsible for passing information to the control electronics about the direct component of sunlight that is available, the diffuse amount of sunlight, the total amount of sunlight and also the differential amount of sunlight on opposing sensors of Wattsun tracking unit, which is currently used in ASU-PTL. With this information obtained, the controller equalizes the sunlight received by opposing sensors for each axis. When there is increased direct sunlight, the controller circuitry adjusts the sensitivity of the tracker automatically and it also decreases the sensitivity when there is diffused light as a result of cloudy conditions. The tracker controller is responsible for sending signals to the DC gear motor, which moves the photovoltaic array to a position where it becomes perpendicular to the rays coming from the sun. The drive motors have two polarities since they are both DC. One of the polarities moves the arrays in the forward direction while the other polarity moves them in the other direction. When the tracker moves to its position where it can start tracking the sun, the controller is stopped electrically which results in greater tracking accuracy and greater power output. The power output of a PV panel is dependent on the amount of direct sunlight that falls on the panel. Moving the PV modules so that they are always perpendicular to the sun maximizes the power output. The increase in power provided by tracking is dependent upon geographic location, season and weather. Power can be increased up to 40% when obtained by the tracking of the sun on a clear day.

Literature search

Literary search was done on the scientific and trade aspects of the concentrator PV trackers. Contact information on the manufacturers of concentrator PV trackers, primarily in the United States and also worldwide was retrieved. The search on the manufacturers was done in order to obtain specifications and manuals to aid in the development of the IEC standard. Information on the method of tracking, advantages of the concentrator PV trackers and the reason why it plays a very important role in the photovoltaics industry was obtained. An experiment, which helped to determine if the sun sensor and tracker were working at an accurate level, was conducted. This experiment involved placing black paper with grid lines on the shading device. This paper was measured to be 4cmwide and 5cm long. Each cell was numbered using the (x, y) coordinate system to enable easier positioning of the sun. It was placed on the detector, which is approximately 18.50 cm from the mirror. A hole was put through the pinhole at point (0,0) to allow the sun to pass through without interference i.e. sun is at direct normal irradiance (DNI) condition.

(-3,5)	(-2,5)	(-1,5)	5	(1,5	(2,5)	(3,5)	(4,5)
(-3,4)	(-2,4)	(-1,4)	4	(1,4)	(2,4)	(3,4)	(4,4)
(-3,3)	(-2,3)	(-1,3)	3	(1,3)	(2,3)	(3,3)	(4,3)
(-3,2)	(-2,2)	(-1,2)	2	(1,2)	(2,2)	(3,2)	(4,2)
(-3,1)	(-2,1)	(-1,1)	1	(1,1)	(2,1)	(3,1)	(4,1)
-3	-2	-1	(0,0)	1	2	3	4
(-3,-1)	(-2,-1)	(-1,-1)	-1	(1,-1)	(2,-1)	(3,-1)	(4,-1)
(-3,-2)	(-2,-2)	(-1,-2)	-2	(1,-2)	(2,-2)	(3,-2)	(4,-2)
(-3,-3)	(-2,-3)	(-1,-3)	-3	(1,-3)	(2,-3)	(3,-3)`	(4,-3)
(-3,-4)	(-2,-4)	(-1,-4)	-4	(1,-4)	(2,-4)`	(3,-4)	(4,-4)
(-3,-5)	(-2,-5)	(-1,-5)	-5	(1,-5)	(2,-5)	(3,-5)	(4,-5)
(-3,-6)	(-2,-6)	(-1,-6)	-6	(1,-6)	(2,-6)	(3,-6)	(4,-6)

Figure 3: Black paper with grid lines was placed on the shading device to identify the location of reflected light

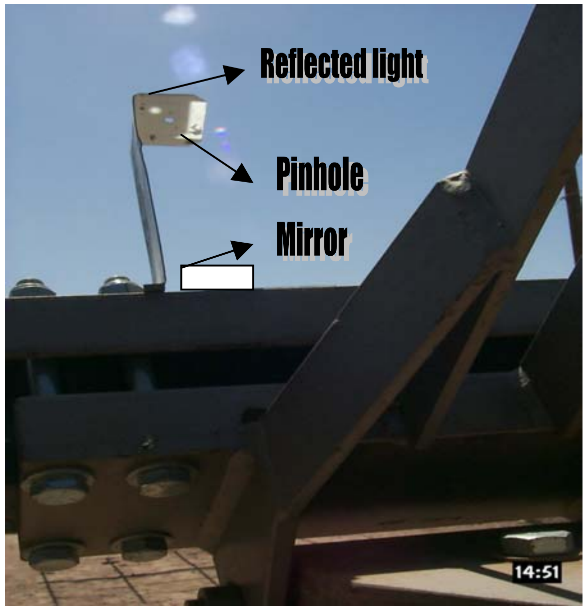

Figure 4: Shading device and its mirror for reflecting the light back.

Date	Time	Location
6/13/2003	9.45a.m	(-1,2)
6/13/2003	10.45a.m	(-1,2)
6/13/2003	11.45a.m	(-1,2)
6/13/2003	12.45p.m	(-1,2)
6/13/2003	1.45p.m	(-1,2)
6/13/2003	2.45p.m	(-1,2)
6/13/2003	3.45p.m	(-1,2)
6/13/2003	4.45p.m	(-1,2)
Date	Time	Location
6/16/2003	9.45a.m	(-1,2)
6/16/2003	10.45a.m	(-1,2)
6/16/2003	11.45a.m	(-1,2)
6/16/2003	12.45p.m	(-1,2)
6/16/2003	1.45p.m	(-1,2)
6/16/2003	2.45p.m	(-1,2)
6/16/2003	3.45p.m	(-1,2)
6/16/2003	4.45p.m	(-1,2)

A stopwatch was used to determine the amount of time it takes for the tracker to move from one position to the next. To achieve this, an average of five different times was taken. The point focus was in the same position from the start of its first movement to the next and so on.

Test	Time (secs)
1	48
2	46
3	47
4	46
5	46

Conclusion
Conducting a literature search on the scientific and trade aspects of the concentrator PV tracker helped in obtaining contact information on the manufacturers of the trackers. These manufacturers are currently in the process of being contacted in order to obtain manuals and specifications on their trackers. Information regarding the method of tracking and performance was also gathered. This information helped in developing ideas for methods of testing and analysis of the trackers. After taking an average of five different times it was found that it takes an average time of 46.6 seconds for the ASU-PTL tracker to move to its next position in the daytime over a period of an observed time of 7 hours each day. And it was found that the point-focus of the sun was located on the same position (-1,2) at the different time intervals. This showed that the sun sensor used for this experiment and the tracker proved to be working in a consistent but inaccurate manner i.e. the spot was always in the same location (-1,2) but it was not at (0,0) meaning there was no direct normal irradiance (DNI). Other test methods will be evaluated and different sensors will be used to ensure accuracy of these trackers.

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3) American Sunco, Retrieved on June 6,2003 from www.acadia.net/sunco/suntrack.html,

Central State University

"Renewable Energy Research Associates Program- An Overview"
Central State University

Clark Fuller, Principal Investigator, August 2003

I. BACKGROUND

Since the early 1990's, Central State University (CSU) has utilized its experience and expertise with the "Northern Senegal Water Management Project" (NSWMP) to form the core in developing the foundation for student training and research under energy programs sponsored by NREL and NASA. The NSWMP is a natural resources project in Senegal, West Africa that is designed to develop self-sufficiency among Senegalese villagers by providing them with the expertise and materiel to install and maintain their own renewable energy water pumping systems (wind and solar energy technology). While under the sponsorship of the NREL scholarship program, the undergraduate students who have participated in the program have learned the basics of wind and solar technology and have focused on research in ways in which photovoltaics can provide new and supplemental energy sources to address the critical shortage of water in many developing countries.

Recently, CSU student research associates have been exploring ways in which renewable energy technologies can be applied to the various modes of transportation. Through a program entitled, "The Summer Transportation Institute", student research associates have sought ways in which renewable energy technology can be applied towards transportation management, transportation safety, transportation technology, and others. The content of this abstract focuses on continuing student research in economic development for developing countries as well as new research topics in the various fields of transportation.

II. OVERALL PROGRAM FOCUS-- ACADEMIC YEAR 2002-03

At least four (4) Central State University students (research associates) participated for ten months in a basic research program that was designed to introduce the students to the practical application of renewable energy technology in the fields of (a) transportation (various modes), and (b.) economic development. The ten month program was divided into two components, (1) Renewable Energy Applications in Transportation; and (2) Renewable Energy for Economic Development. Also, during the summer of 2003, Central State University partnered with NREL to support two (2) Central State University undergraduate students and two (2) student research associates from other universities to conduct research internships at various laboratory locations throughout the United States.

III. SCOPE OF WORK, 2002-2003

A. Renewable Energy Applications in Transportation

The research associates were required to perform design and problem solving tasks in order to complete working transportation models powered by renewable energy. While under the guidance and leadership of professors within the Department of Manufacturing Engineering and Water Resources Management, students performed up to 20 hours per week on research projects that had a transportation theme.

Further, as part of a collaborative partnership arrangement between Central State University, the NASA Glenn Research Center and the Ohio Division of the Federal Highway Administration, the Office of Sponsored Research combined and expanded its Renewable Energy Research Program to include student research projects as they apply to the various fields of transportation. The exploratory research projects included (among others) the design phase for future construction of a solar car; a feasibility study (with guidance from the Ohio Department of Transportation) regarding solar lighting and heating for bus stops; a design plan for solar lighting along CSU's Tawawa Apartments walkway; and, the design and construction of a solar charging station for CSU's electric carts (used in materials management).

The outcome of the projects as described above were integrated into a revised, four-week summer transportation institute for high school students (summer, 2003) that now includes a renewable energy theme.

B. Renewable Energy for Economic Development

Central State University Research Associates collaborated with the "African Solar Village Outreach Program" (ASVOP) and the Foundation for Environmental Education for the installation of a 1kw photovoltaic system at Martin Luther King Middle/ High School in the Hough community in Cleveland, Ohio. The system is the first at an African American urban school in Ohio, and the first in Ohio to participate in the Million Solar Roof Initiative. The installation is an effort to stimulate the deployment of renewable energy into the African American urban community. It will also be utilized as a hands-on educational tool for high school mathematics and science teachers in illustrating the benefits of clean renewable energy. Central State University research associates traveled to Cleveland, Ohio during several weekends to complete the project.

IV. TASKS INITIATED OR COMPLETED BY PROGRAM STAFF, FACULTY AND RESEARCH ASSOCIATES—AY 2002-03

- Coordinated proposed student tasks and projects with collaborating partners and institutions (Wilberforce University. Columbus State Community College, Cleveland African American Museum, Martin Luther King High School and the NASA Glenn Research Center);
- Performed student orientation sessions and provided student research assignments;
- Initiated the design phase for the future construction of a solar car;
- Initiated a study and survey for recommending solar heating and lighting for local commercial (or private) bus stops;
- Completed a design plan for solar lighting along Central State University's Tawawa Apartments walkway;
- Designed a solar charging station for three Central State University' materials management electric carts;
- Completed a research study- "Solar Water Heater as Pyranometer"
- Installed a 1kw photovoltaic system at Martin Luther King Middle/High School, Cleveland, Ohio;
- Included and integrated a one-week renewable energy theme into CSU's 2003 Summer Transportation Institute for high school students;
- Completed four (4) renewable energy internships (Summer 2003) at the following locations:
    1. Tehron Jones, Texas Southern University, REAP Program;
    2. Kevin Johnson, National Renewable Energy Laboratory, Golden CO;
    3. Jessica Newton, Kent State University, NEOBeam Laboratory
    4. David Martin, Central State University, Summer Transportation Institute.

Point of Contact: Clark Fuller
Associate Director and Principal Investigator
Office of Sponsored Programs & Research
Central State University, P.O. Box 1004
Wilberforce, Ohio 45384
Phone: (937) 376-6312
Fax: (937) 376-6598
E-Mail: cfuller@prodigy.net
cfuller@csu.ces.edu

ABSTRACT

"African Solar Village Outreach Program (ASVOP) and Central State University (CSU) Intern Research Project-- lKW Photovoltaic Installation at Martin Luther King (MLK) High School"

Qadwi Bey, ASVOP Project Manager, August, 2003

The installation of a solar power-generating unit was the culmination of the work that has been done by the CSU Interns over the last three years. The ASVOP renewable energy project focused on renewable energy in general and photovoltaics specifically. During the weekend of July 12, 2003, the CSU-Interns along with the staff of ASVOP installed the first PV system designed and installed at an African American Inner-City School by African Americans. This was a Historic Moment. From here ASVOP will continue its partnership with CSU on other renewable projects both here and abroad, starting with ASVOP's Traveling African Solar Village Exhibit to be displayed during the Summer 2003 Transportation Institute and the African Cultural Festival in Dayton, Ohio.

The details describing the tasks and the hands-on work requirements for the students will be presented during a briefing at the Renewable Energy Academic Partnership (REAP) Conference in Phoenix, Arizona, August 4-9, 2003.

Central State University

"The Effect Of Electron Beam Radiation On Photovoltaic Cells"

Jessica Newton
Central State University Team, August, 2003

Background:

While under the simultaneous sponsorship of Central State University's Renewable Energy Research Associates Program and the National Renewable Energy Laboratory, Jessica Newton completed a Summer 2003 internship at the Electron Beam Technology Laboratory, Kent State University, Middlefield, Ohio. This industrial facility offers a full range of educational, research, development and production opportunities in the field of radiation processing using electron beams.

Research Project

As a student intern, my mission was to conduct research on solar technology projects at Kent State University involving Characterization of Materials with Electron Beam Spectroscopy. The content of my presentation to be made at the REAP Conference in Phoenix, Arizona on August 6, 2003 will include the following:

First, I will give a description of the components of a solar cell, then I shall discuss in detail the characteristics that have a direct effect on the operation of a solar cell. Following this I will proceed into discussing what an electron beam is, what it does and it's significant for this entire project. In addition to this, I will also discuss the effects of radiation on photovoltaic cells. The results and conclusion of this project are based upon the experiments of the electron beam and the cells.

Some aspects of my research coincided with other ongoing research at the NEO Beam facility. This included: 1) A need to fully characterize the LMS-3 (a computer-controlled system to do irradiation of samples), and to use it to irradiate samples that NEO Beam is likely to obtain from a commercial vendor, via Naval Research Laboratories; and, 2) The need for the development of a standard practice (ISO) for the irradiation of cells used in space applications. Some discussion of these topics may (or may not) be included in the REAP presentation.

Clark Atlanta University

Results Produced by the Historically Black Colleges and Universities (HBCU) Photovoltaic Research Associates Program at Clark Atlanta University

Gerald W. Grams and Randal L. N. Mandock
Clark Atlanta University, Atlanta, Georgia.

1. Introduction

This program provided financial support and research opportunities for undergraduate students to enhance their knowledge in the field of photovoltaic research and to encourage them to pursue careers in photovoltaics. A major goal of the research part of this program was to determine the effects of atmospheric variability on the production of solar energy by photovoltaic sources. Another goal was to provide our students with opportunities for obtaining a background in modeling and design optimization of solar cells.

2. Approach/Background

Research activities initiated by past collaborations between Clark Atlanta University and Vista University in Port Elizabeth, South Africa, helped shape a major part of the research effort initiated under this program. The primary goal of that work had been to determine the effects of atmospheric variability on the production of solar energy by photovoltaic devices. A combination of solar radiation measurements, meteorological observations, and computer modeling work was used to carry out an assessment of the efficiency of operation of photovoltaic modules under different atmospheric conditions. We also developed a collaborative project with Dr. Godfrey Augustine of the Northrup Grumman Science and Technology Center who had a background in modeling and design optimization of Indium Phosphide solar cells and who volunteered to mentor a student on such a project.

3. Atmospheric effects on production of solar energy

The Earth System Science (ESS) program at Clark Atlanta University (CAU) operates an Atmospheric Optics Observatory (AOO) on the roof of the Research Center for Science and Technology. The AOO provides a platform for a variety of instruments to monitor the amount of solar energy reaching Earth's surface throughout the day. An automated weather station at the AOO site provides simultaneous data on atmospheric pressure, temperature, humidity, wind speed, and wind direction. A combination of solar radiation measurements, meteorological observations, and computer modeling work is used to carry out assessments of the efficiency of operation of photovoltaic modules under different atmospheric conditions. To improve our ability to interpret data obtained by the radiation sensors, CAU developed a simple, inexpensive atmospheric haze sensor that uses an LED (light-emitting diode) as a narrow-band detector. Six different LED wavelengths are available, and data from such a device operated throughout the day can be used to determine the fraction of incident solar energy that has been lost due to the presence of haze (aerosol particles) in the atmosphere as a function of wavelength.

Work began on the development of the LED haze sensor during the summer of 1999 by Bryant Pierson and Akil Sutton (physics majors from Morehouse College). A working model was completed and preliminary measurements were obtained prior to the First REAP Conference in Baton Rouge, LA, in August 1999. In the following year, additional efforts were carried out to optimize the performance of the LED haze sensors and to develop the computer software required for analysis of data. Adwoa Gyekye (a CAU physics major) carried out tests and routine observations with the new sensor in Summer 2000 to evaluate the operation and accuracy of the instrument. These results were reported by Bryant Pierson at the Second REAP conference in Denver in August 2000. Ms. Gyekye joined the PV Associates program as an undergraduate research assistant in Fall 2000 to continue working with the ESS research staff on testing and evaluating the instrument as it underwent several modifications to make it simpler and easier to operate. Mr. Ashanti Smarr from Atlanta Metropolitan College operated the instrument and worked on data analysis procedures in Summer 2001. Mr. Smarr presented results obtained with the sun photometer at the Third REAP Conference in Houston in August 2001. Mr. J. Lamar Dorsey from Atlanta Metropolitan College and Mr. Cleon M. Long from Morehouse College operated the instrument and worked on data analysis procedures in Summer 2002. Mr. Dorsey presented results obtained with the device at the Fourth REAP Conference held in Washington DC at Howard University in August 2002. The development work on the instrument has been completed, and a technical paper will be prepared for publication in a scientific journal.

Mr. Lamar Dorsey, PV Associates Undergraduate Research Assistant
from Atlanta Metropolitan College
operating one of the most recent models of the CAU sun photometer

4. Solar Heating of Houses

A project began during the summer of 2000 to assess the effects on heating of buildings by proximity to different natural and artificial structures and to different natural and artificial surfaces. Sunlight reflected by these surfaces and heat radiated were to be measured by an array of six net radiometers positioned in the vicinity of four small houses. Six Fritschen net radiometers have subjected to an intercomparison study to determine equations which will compensate their systematic differences from one another. The dependence of radiometer position in the calibration array was also studied as part of this program.

5. Renewable Energy Availability in Georgia

In 2002, two projects were initiated to assess the availability of solar and wind energy throughout the state of Georgia. Monthly, seasonal, and annual integrated insolation measurements for six Georgia Automated Environmental Monitoring Network (AEMN) stations have been compared to a clear sky model to assess the potential for solar energy production in Georgia. Multi-year data have been analyzed for trends in annual accumulated insolation values. Locations most favorable to solar energy production have yet to be identified. The wind energy potential has also been calculated for monthly, seasonal, and annual integrated wind speed measurements recorded by six AEMN stations in Georgia.

6. Modeling and Design Optimization of Solar Cells

This activity has been conducted as a collaborative project with Dr. Godfrey Augustine of the Northrop Grumman Science and Technology Center. Dr. Augustine has a background in modeling and design optimization of Indium Phosphide solar cells, and he volunteered to mentor one of our students for the project. Mr. Robert Easley, a Physics and Mathematics major from Morehouse College began working with Dr. Augustine during the Fall 1999 semester. A research effort was initiated to carry out literature searches and to update an existing model for optimizing the design of InP solar cells for higher efficiency and greater radiation tolerance. The PC-1D computer program was purchased from the Photovoltaics Special Research Centre at the University of New South Wales in Sydney, Australia. This program solves the fully coupled nonlinear equations for the quasi-one-dimensional transport of electrons and holes in crystalline semiconductor devices, with emphasis on photovoltaic devices. The program was installed on a computer in our laboratory, and Mr. Easley worked with the program under the guidance of Dr. Augustine. Mr. Easley was able to continue this work while serving as an intern at NREL during Summer 2000, and results of his work on this project were described at NREL's Second REAP Conference in Denver in August 2000. During the past two years, he continued using the PC-1D program to carry out systematic studies to examine changes in the maximum power output of InP solar cells. He served again as an intern at NREL during Summer 2001 and Summer 2002. Mr. Easley attended the 2001 REAP Conference in Texas Southern University in Houston in August 2001 where he received the Dr. Joshua Hill Award for outstanding intern at NREL. He also attended the 2002 REAP Conference in Washington, D. C.

Mr. Robert Easley, PV Associates Undergraduate Research Assistant
from Morehouse College
working on project to optimize the performance of solar cells.

7. Conclusions

The PV Research Associates Program supported fourteen students since inception. Those students completed a considerable amount of research during the program. The enthusiasm that they acquired as they obtained their results added a new feature to their activities – speaking and presenting posters describing their research projects to other students at other universities and organizations. In 2000, one of our Undergraduate Research Assistants, Mr. Robert Easley, began speaking and presenting posters describing his research project to other students at other universities and organizations. Other students followed his example. In the past 4 years, six of the students supported by this program made more than 20 presentations describing their research at scientific meetings and undergraduate research symposiums and exhibitions held at other universities including Bowie State University, Howard University, Jackson

State University, Morehouse College, and Tuskegee University. These activities served to introduce students not directly supported by the PV Associates program to the field of photovoltaic research and thereby provided encouragement to other undergraduate students to pursue careers in photovoltaics.

8. Posters and Presentations

A partial list of poster and oral presentations made by CAU PV Associates Undergraduate Research Assistants during the program is presented below.

Chen, Amy P., S. D. Fischer, R. L. N. Mandock, G. W. Grams, and G., Hoogenboom. "Estimation of Cloudiness and Solar Energy Availability in Georgia Using a Clear Sky Model", NREL Renewable Energy and Academic Partnerships (REAP) Conference, August 5 – 8, 2002, Howard University, Washington, D. C.

Copridge, Joi, R. L. N. Mandock, and G. W. Grams, "Intercomparison of the Response of Six Net Radiometers and Implications for Studies of the Effects of the Solar and Infrared Radiation Fields on Heating and Cooling Requirements in Urban Areas', NREL REAP Conference, August 5 – 8, 2002, Howard University, Washington, D. C.

Dorsey, J. Lamar, R. L. N. Mandock, G. W. Grams, M. L. Blyler, and S. D. Fischer, "Measurements of Total Atmospheric Extinction due to Atmospheric Aerosols and Water Vapor using Observations Obtained with the CAU Multiple-Wavelength Sun Photometer", NREL REAP Conference, August 5 – 8, 2002, Howard University, Washington, D. C.

Easley, Robert L. Jr., "Quantifying the Calibration Biases due to the Field of View and the Window Transmittance of the Eppley Normal Incidence Pyrheliometer", NREL REAP Conference, August 5 – 8, 2002, Howard University, Washington, D. C.

Easley, Robert L. Jr., "The Uncertainty Envelope Construct Applied to Direct Solar Radiation Data Quality Assessment," NREL REAP Conference, August 8 - 11, 2001, Houston, Texas.

Easley, Robert L. Jr., "Quantum Efficiency Maximization", Clark Atlanta University Undergraduate Research Conference, May 2001, Clark Atlanta University, Atlanta, Georgia.

Easley, Robert L. Jr., "Quantum Efficiency Maximization of Solar Cells," Poster Presentation, Beta Kappa Chi Undergraduate Research Conference, March 31, 2001, Atlanta, Georgia.

Easley, Robert L. Jr., "Modeling the Performance of Indium Phosphide Solar Cells," Poster Presentation, Tuskegee First Annual Science Research Exhibition, October 14, 2000, Tuskegee, Alabama. *This presentation received first prize in the Aerospace Engineering, Mechanical Engineering, and Physics Division at the Exhibition.*

Easley, Robert L. Jr., "Modeling the Performance of Indium Phosphide Solar Cells," Poster Presentation, Morehouse College First Annual Science and Mathematics Research Exhibition, September 7, 2000, Atlanta, Georgia.

Easley, Robert L. Jr., "Modeling the Performance of InP Solar Cells," NREL Renewable Energy and Academic Partnerships (REAP) Conference, August 9 - 11, 2000, Golden, Colorado.

Easley, Robert L. Jr., "Modeling the Performance of Indium Phosphide Solar Cells," Poster Presentation, Howard University Third Annual Atmospheric Science Conference, March 20–22, 2000, Washington D. C.

Gyekye, Adwoa K., G. W. Grams, R. L. N. Mandock, B. R. Pierson, and M. L. Blyler, "Measurements of the Total Atmospheric Extinction due to Atmospheric Aerosols and Water Vapor using Multiple-

Wavelength Sun Photometer Observations", Poster Presentation, NOAA CIRE (Collaborative to Integrate Research and Education) Symposium, Bowie State University, Bowie, MD, May 4, 2001

Gyekye, Adwoa K., "Determination of the Optical Effects of Atmospheric Aerosols using Sun Photometers", Poster Presentation, to be presented at NOAA Conference on Expanding Opportunities in Oceanic and Atmospheric Sciences, Jackson, MS, 1 - 3 April, 2001.

Gyekye, Adwoa K., "Using the Sun Photometer to Determine Extinction due to Aerosols and Water Vapor," Oral and Poster Presentations, Research Experiences for Undergraduates in Earth System Science at Clark Atlanta University, July 28, 2000, Atlanta, Georgia.

Holley, Alisa, G. W. Grams, R. L. N. Mandock, S. D. Fischer, and M. L. Blyler, "A Comparison between Atmospheric Extinction Data obtained by an Automated Multi-Spectral Rotating Shadowband Radiometer (MFRSR) and the CAU Multiple-Wavelength Sun Photometer", NREL REAP Conference, August 5 – 8, 2002, Howard University, Washington, D. C.

Mandock, Randal L. N., S. D. Fischer, O. Fayanjuola, G. W. Grams, G. Hoogenboom, and A. P. Chen, "Renewable Energy Availability in Georgia: A Study Using Data from the Georgia Automated Environmental Network (AEMN)", NREL REAP Conference, August 5 – 8, 2002, Howard University, Washington, D. C.

Pierson, Bryant R., "The Development of a Sun Photometer for the Measurement of Haze," Poster Presentation, Howard University Third Annual Atmospheric Science Conference, March 20 – 22, 2000, Washington, D. C.

Pierson, Bryant R., "Atmospheric effects on production of solar energy," NREL REAP Conference, August 9 - 11, 2000, Golden, Colorado.

Smarr, Ashanti, "Using Multiple-Wavelength Sun Photometer Observations to Determine the Effects of Atmospheric Variability on the Production of Solar Energy by Photovoltaic Devices," NREL REAP Conference, August 8 - 11, 2001, Houston, Texas.

Smarr, Ashanti, "Using Multiple-Wavelength Sun Photometer Observations to Determine Extinction due to Aerosols and Water Vapor," Oral and Poster Presentations, Research Experiences for Undergraduates in Earth System Science at Clark Atlanta University, July 28, 2001, Atlanta, Georgia.

Clark Atlanta University

Developing an AFM Simulator

Chinua Bakari Mosley
Clark Atlanta University
Atlanta, Georgia

Atomic Force Microscopy (AFM) is one of several techniques used in the analysis of the structure of surfaces. AFM interacts with the surface of a sample with an extremely fine tip that is only a couple of microns long, and through various techniques we can determine up to the atomic level how a surface is. But this method is not 100% accurate. With a program that emulates the interaction between surface and tip we can get a better understanding on how various tips will react to various surfaces. Hopefully the simulator will also give us a better understanding to the point where we can improve our current technologies by making them more accurate and reliable. Therefore my project is to develop a program that accurately emulates contact AFM. Contact AFM is the AFM technique in which the tip makes soft physical contact with the surface.

To get a better understanding of AFM I've read several documents on AFM including "A Practical Guide to Scanning Probe Microscopy", by TM. I also read several documents on photovoltaics which are the materials being analyzed. Photovoltaics are materials with the unique ability to convert sunlight into electricity. In addition I have attended a mini course at the School Of Mines on AFM techniques.

My approach is a step by step process; putting together the program in the order the user would use it. I did this by creating the menu bar first, then the control panel, and display area. Also in my approach I'm trying to make the program as understandable and user friendly as possible. I am even filling the code full of notes so that a novice programmer can easily come behind me, understand my methods, and make changes or improvements if need be. Other considerations in the design of the program include speed, visual appeal, and making sure that the program accurately simulates in an understandable fashion what exactly goes on during AFM.

The programming consists of a lot of trial and error. Programs almost never run smooth the first couple of times so frequent debugging is to be expected. There are a million and one ways to do any application so brainstorming and planning are done to figure out the best possible set of algorithms, functions, and variables to make the application run correctly. The finished project being a smooth running application that's easy to use.

Fisk University

Semiconductor Quantum Dot Based Solar Cells

Richard Mu
Fisk University
Department of Physics
1000 17th Avenue N
Nashville, TN 37208

Semiconductor quantum dots have a great potential to be the future solar cell materials. The two major un-parallel properties as opposed to the bulk counterparts are the tune ability of the optical band gap and the enhancement of the oscillator strength. However, continued efforts are needed to precise control of particle size, shape and size distribution so that the quantum dot based solar cells can become reality. Pulsed laser ablation has been used to produce silicon nanocrystals. Variation of the laser fluence, backing gas type and pressure result in nanocrystals with controllable size distributions. Properties of nanocrystals produced with this method also depend on the distance of the nanocrystal from the center of the laser plume. Correlated atomic force microscopy and in-situ micro-Raman measurements confirm that particle size decreases as distance from the plume center increases. Silicon peaks in the micro raman spectra taken at increasing distance from plume center show considerable differences in both center energy and width. Confocal micro raman spectra from thicker (> 10 micron) samples show little variation with depth, in contrast with porous silicon samples.

Working with The FEMP Technical Assistance Team

Kevin Jahi Johnson
Florida A&M University
Tallahassee, Florida

It is important to conserve energy in this day and age by using cost-effective alternatives to fossil fuel. Renewable energy is the first step towards creating an energy-efficient, sustainable future. Technologies such as photovoltaics, biomass energy, wind power, and geothermal resources have been in development over decades, improving over time and yielding more energy to become a viable alternative. However, while these cutting-edge technologies must be further developed, they must also be implemented into existing or newly constructed buildings and facilities to convey their status as a competitive option. Therefore, these alternative energy resources must be put to good use and demonstrated to the global community.

The Federal Energy Management Program, or FEMP, has the responsibility to aid and assist Federal agencies that wish to incorporate renewable energy into Government operations. These renewables also have the potential to save thousands of dollars in utility costs and to cut back on pollution caused by years of conventional energy usage. Virtually all of FEMP's clientele includes many Federal agencies and military construction sites, which benefit from FEMP's publications and resources. By working with FEMP, these agencies now have the choice and ability to tap into abundant resources and to function in a cleaner, more cost-effective manner.

OPTIMAL POWER DISPATCH OF A PV SYSTEM WITH GAUSSIAN DISTRIBUTED LOAD.

James A. Momoh, FIEEE, Robert Sowah,
Howard University, Center for Energy Systems and Controls, 2300 6TH Street
Washington, DC 20059.
Fannie Posey Eddy,
National Center for Photovoltaics
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, Co 80401

ABSTRACT

The paper addresses the performance of the maximum power tracking of PV system connected to a load. The sensitivity of different fault levels, insolation and load condition is studied. An intelligent maximum power tracking consisting of the application of Genetic algorithms to track the PV power under different peaking points is described. The optimized PV operating point is used to supply the distribution network.

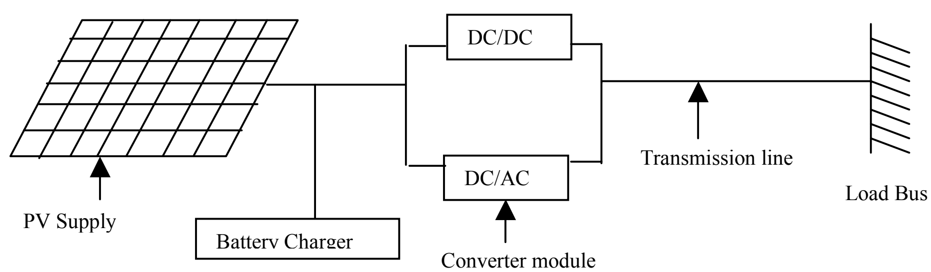
The performance of the integrated scheme using different fault levels, loads, insolation levels is used to evaluate the system stability of the network. To extend the integrated package to handle different load profiles is the core of this paper. This involves tracking of dynamically changing PV over time to meet a Gaussian distributed load.

To accomplish optimal dispatch, a Monte Carlo process is developed to model the load in Gaussian form. The scheme is tested using a topology based on a 32-bus radia distribution network in [7]. To demonstrate the performance of the integrated PV system under different load conditions.

PROBLEM DESCRIPTION

Consider the simplified power system network below with PV as a distributed generation resource with transmission links and loads.

The objective is how to optimally track and dispatch power to meet load demand which is Gaussian distributed in nature, subject to transmission system constraints.



This takes into account optimal PV system structure, power management with system reliability, efficiency and solution of the power quality problem under uncertainties.

The overall scheme of the proposed integrated scheme is divided into the following modules namely:

1. Insolation level forecasting using Artificial Neural Networks
2. PV maximum power tracking using Genetic Algorithms
3. Development of optimization dispatch scheme for tracking of PV power to different loads such as uniformly and Gaussian distributed loads.
4. Reliability module consisting of loss of load probability (LOLP) and Expected Unserved Energy (EUE) under different contingencies is done.

CONCLUSION.

The integrated scheme has been tested on 32-bus radial system and the results are very encouraging. The complexity and sensitivity analysis gave promising results and thus capable of assessing PV performance under varying conditions with a modeled Gaussian distributed load. The impact of congestion was evaluated using the integrated scheme which shows stability of the network was not compromised due to varying load conditions.

FUTURE WORK.

To complete the project in the near term, we plan to compare the experimental method against an optimization based unit commitment with transmission line constraints.

We plan to develop a control strategy to overcome the low reliability and instability due to the Gaussian distributed load. This will be useful to guide future operators, planners as well as decision and policymakers in design and operation of PV Power systems.

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North Carolina Central University

HBCU PV Research Associates Program
At
North Carolina Central University

Investigation of Photovoltaic and Thermophotovoltaic Semiconductors

Review of this project is presented by: Dr. J. M. Dutta (PI)

Our primary focus is to train selected students in research in fabricating and characterizing various bulk and nanophase photovoltaic materials. Cross-over phenomena on going from clusters to nanocrystals to the bulk is another focus of the research. The purpose of the program is to facilitate basic research and training in the energy-related technology. Over the last few years, at North Carolina Central University (NCCU), significant progress has been made in developing a semiconductor research program, supported by the National Renewable Energy Laboratory (NREL). Recently we have been successful in acquiring several high power scientific apparatus, which will considerably enhance on-campus research capability for our students and faculty.

Low temperature crystallization and defect annihilation studies of thin a-Si films by exposure them to the FEL beam at certain wavelengths, and scanning over a range of different pulse durations and energies, has been continued during this reporting period. Two sets of 200 μm thick samples, one set of a-Si:H deposited on glass by hot wire deposition method at NREL and the second set deposited on mono crystalline Si substrate were exposed to 5 μm IR radiation at Vanderbilt University FEL. Intensities were chosen to be 2.4 KJ/cm^2, 4.8 KJ/cm^2, and 7.2 KJ/cm^2. The structural, optical, electrical and other properties were measured before and after exposure. Our preliminary results from Raman analysis confirm our earlier results on the improvement in the Short Range Order (SRO) and intermediate Range Order (IRO) after irradiation with the peak power density between 100 MW/cm^2 and 1000 MW/cm^2. At power lower than 100 MW/cm^2 the effect was not observed and at 1000 MW/cm^2 the process of crystallization starts. Details will be presented at the meeting.

Capacitance measurements of depletion layers in semiconductors are widely used in the characterization of electrically active levels due to the presence of impurities and point defects. By time resolved capacitance spectroscopy, "Deep Level Transient Spectroscopy," (DLTS), electronic properties of such levels, activation energy, the carrier capture, and emission processes can be studied directly. DLTS also permits to gather information on trap concentrations, depth profile of the trap concentration, and others. We used DLTS for investigation of deep levels in polycrystalline Edge-defined Film-Fed Grown, EFG silicon (low-cost solar cells), as well as monocrystaline Czocharlski and Float Zone silicon. Some of our recent research on EFG samples will be presented. Recently we have acquired a DLTS apparatus, made by Sula Technology Corporation. Its performance characteristics will be presented.

One of our objectives has always been to establish an on-campus facility to fabricate quantum dots (QDs) and capability to deposit multi-layer thin films by Pulsed Laser Deposition (PLD) techniques. For that purpose, the chamber that will be used for the productions of QDs and the deposition of thin films has been designed and is being assembled at this time. A pulsed laser and a pulsed electron gun will be attached to the chamber and used to sputter a sample to a substrate. Design scheme and the progress in assembling its various parts will be presented.

To gain experience with the pulsed laser deposition scheme, we have initiated a research collaboration with one of the research institution in India. The experimental set up and some of the preliminary results of our studies performed on a thin a-Si:H produced by PLD will be presented.

In multijunction solar cells, the individual solar cells are stacked on top of each other to maximize the range of absorption in the solar spectrum. For example, a four-junction combination (i); an AlGaInP (Eg=2.0eV) top cell; a GaAs (Eg=1.43eV) second-layer cell; a third-layer of GaInPAs (Eg=1.05eV) and a Ge (Eg=0.67eV) substrate as the bottom cell has a theoretically predicted efficiency of 42%.

Quantum dots solar cells provide a possibility to further increase the efficiency of solar cells by introducing an intermediate band between the semiconductor's conduction band and valence band (ii). This enables the absorption of two extra photons lower than the band gap of the material. Theoretical calculations have indicated that solar cells with an intermediate band have a potential efficiency of 63.2%.

However, the synthesis of such high efficiency solar cells has still to be demonstrated. One of the main technical problems is the stress that appears, because of mismatch in the lattice between various materials. Because of the differences in the thermophysical properties between films, quantum dots, and substrate materials, residual stresses are introduced during and after cooling down from the growth temperature to room temperature. During this reporting period effort has been made in numerical modeling of residual stress and electronic states in both thin films and quantum dots for understanding the relationship among various growth parameters. Numerical simulation results will be discussed and compared with available experimental data.

Participants:

Faculty:	Research Associates:		
		Christian Harris	Duke Univ
		Mariamma Kambon	Florida A & M
J. M. Dutta (PI)		Dana M. Warren	NC State
B. Vlahovic		D. Sunda Meya	
Kai Wang		Justice McConnel	
V. Borjanovic		Marcia Archibald	Georgia Tech
		Darek Woods	
		Ashley Holley	

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North Carolina Central University

Design and Construction of the Chamber for Thin Films and Quantum Dots Fabrication

B. Vlahovic

One of the promising approaches to improve the efficiency of solar cells is to employ multilayers, in which, the individual solar cells are stacked on top of each other to maximize the range of absorption in the solar spectrum. For example, a four-junction combination[iii]; an AlGaInP (Eg=2.0eV) top cell; a GaAs (Eg=1.43eV) second-layer cell; a third-layer of GaInPAs (Eg=1.05eV) and a Ge (Eg=0.67eV) substrate as the bottom cell; has a theoretically predicted efficiency of 42%.

Most of the methods for growing multilayer thin films rely on epitaxial layer deposition on a variety of substrates at higher temperatures. Between various thin film deposition techniques, Pulsed Laser Deposition (PLD) using laser pulses of nanosecond duration carries the advantage of having high kinetic energy particles available for film deposition.[iv,v] The high kinetic energy of the ablation species contributes to better quality of epitaxial layers, which are deposited at a much lower substrate temperature compared to other techniques. For example, smooth epitaxial Ti doped sapphire films have been reported at a substrate temperature as low as 650 ^{o}C by PLD in contrast to 1200 ^{o}C by other techniques.[vi,vii] Film deposition at lower substrate temperature will be of interest to multilayer deposition in order to minimize the interdiffusion of species between different layers. Additionally, the thermal strain developed between layers during the cooling to room temperature can be reduced. The relatively simple experimental geometry of PLD enables to use appropriate background partial pressure both to maintain the film stoichiometry and to appropriately moderate the kinetic energy of the ablated species[viii] for better epitaxial film quality.

We are currently in process of developing a PLD and pulsed electron gun facility in NCCU and deposit individual layers of AlGaP, GaAs, GaInPAs and other layers of related interest followed by multilayers. Thin films will be deposited under different laser fluence and background conditions in order to characterize the role of kinetic energy of the depositing species on the film-substrate interface stresses. Insitu monitoring of epitaxial growth by reflection high energy electron diffraction (RHEED) will reveal structural information of the epitaxial growth after each laser pulse during early stages of epitaxial film growth.[ix] The RHEED information will be compared with the results of Raman spectroscopy described in the next section and the interface between heterolayers will be modeled. Deposition of ultra-thin films and their characterization as a function of film thickness will be undertaken. Film deposition on different substrates will be carried out in order to provide more experimental data for numerical computation and modeling of the film-substrate residual stress as described in the above sections.

The key technological challenge of GaAs film formation on Si substrate is the large stress at the interface due to lattice mismatch.[x] Characterization of GaAs-Si interface versus film thickness, as an experimental parameter, will be done on the films deposited by PLD and pulsed electron gun technique. Similar work will be undertaken by introducing a thin buffer layer, such as $SrTiO_3$, which has an intermediate lattice constant between GaAs and Si. The expected outcome will help towards low cost solar cells development, and more versatile Si wafers in place of Ge. Apart from providing avenues for the research goal, in addition the NCCU students will be exposed to the NCCU state of art thin film deposition technique.

One of the problems encountered by PLD are the particulates observed during ablation use of nanosecond (ns) laser pulses. A major source of particulate emission from the target is the resolidification and the recoil pressure below the vaporizing front in the molten volume. The thermal diffusion depth, a function of the laser pulse width, is very small when a pico second (ps) pulse is used for ablation, if compared to ns pulses. This produces much smaller molten volume with a large temperature gradient and hence can reduce both the particulate emission[xi] and the ablation threshold.[xii,xiii] A typical micro pulse energy of 1 mJ per pulse at 1 ps width corresponds to an instant power of 1 GW, an appreciable value for laser ablation studies. We will also explore the wavelength tuneability of FEL that will provide advantage of selecting appropriate wavelength for ablation and the high repetition rate will enables much higher deposition rates compared to excimer lasers. High deposition rate enables to have longer target to substrate distance, and to obtain spatially uniform thin films over a large substrate area.[xiv] However, the physics of laser ablation and thin film deposition using ultra short laser pulses is still not well studied. We will later upgrade our facility to deposit thin films and to characterize the laser ablated species by time of flight mass spectrometry technique and carryout deposition of different layers and multilayers towards developing high efficiency solar cells. We will compare the films deposited using nanosecond laser pulses from excimer laser and (sub) picosecond electron gun pulses and laser pulses from FEL.

Preliminary results on a-Si:H thin films deposition by PLD

To gain an experience with the Pulsed Laser Deposition, necessary for better design of the facility we already started production of thin a-Si:H films by Pulsed Laser Deposition. Since our deposition chamber that will have attached both pulsed laser and pico second pulsed laser is still under construction we decided to carry out our preliminary research in collaboration with Indira Gandhi Center for Atomic Research, Kalpakkam, India. The experimental setup that we used consist of a Q-switched Nd:YAG laser (M/s Continuum Model NY/6 1, USA) operating at 532 nm, TEM_{00} mode, having a pulse width of 8 ns, repetition rate of 10 Hz and a pulse energy of about 40 mJ. A quartz lens with a focal length of 25 cm is used for focusing the laser beam and the target is positioned after the focus. The laser power density is varied from $1.3x10^7$ to $8.9x10^8$ W/cm^2 by adjusting the distance between the focusing lens and the target. The target is mounted on a remotely controlled micro-positioner to have a controlled target movement for better control of the deposition process. A base pressure of 10^{-8} torr is maintained by differentially pumping the chamber with a cryopump..

Series of samples were deposited. Irradiated power on samples is changed from $1.8x10^7$ Watts/cm^2 to $8.9x10^8$ Watts/cm^2, using pulse energy of 30 mJ, pulse with of 8 nano seconds and repetition rate of 10 Hz. For the target, which was on the distance of 5 cm from the substrate we used intrinsic crystalline Si. Deposition was done on various substrates: 7059 glass, amorphous quartz and si(111) wafer. The samples are also deposited at the different substrate temperatures that varied from 25 ^{o}C to the 200^{o}C. The samles are also deposited in vacuum ($2x10^{-6}$ Torr, and in H_2 atmosphere that was varied from $5x10^{-3}$ to 760 Torr. Finally, after deposition some samples were annealed at 250^{o}C under 1 Torr of H_2 atmosphere. All samples are being irradiated by IR FEL radiation in order to improve intermediate and short range order. Some characterization of the samples is already done. The preliminary results will be presented.

Multi-junction and quantum dots cells are being forecasted for the next generation high-efficiency solar cells. Despite the theoretical prediction of 42 % and 63 % photovoltaic conversion efficiencies respectively for 4-junction and quantum dot based cells, such devices are still to be realized.

One proposed method for increasing the efficiency of solar cells is to introduce an intermediate band between the semiconductor's conduction band and valance band. This enables the absorption of two extra photons lower than the band gap of the material. Theoretical calculations have indicated that solar cells with an intermediate band have potential efficiency of 63.2 %. It has been shown that the intermediate band can be formed within quantum dots (QD) from the intermediate confined state induced by the quantum dots. The quantum confinement effect occurs when the photoexcited electron and hole pairs are spatially confined within the particles.

Many approaches to fabricate silicon quantum dots have been reported, which include ion implantation, combustion of SiH_4, spark processing, plasma chemical vapor deposition etc. Techniques like molecular beam epitaxy (MBE), sputtering, and pulsed laser deposition (PLD) produce QDs that are clean and impurity free. Most popular among them is the formation of ordered arrays of self-assembled QD islands through Stranski-Krastanow (SK) method.

Ion implantation provides a direct way of fabricating QDs in dielectric hosts. Other approaches require complex chemical methods which invariably lead to impurities being incorporated into the QD as well as the host dielectric matrix. Ion beams are isotopically clean and therefore do not have the inherent impurities which are present in chemical synthesis. Moreover, ion implantation is not constrained by the equilibrium thermodynamics which limit how much QD material can be incorporated in a melt phase (e.g. dissolving CdSe in a glass). Ion implantation is a brute force method which circumvents the constraints imposed by equilibrium thermodynamics; we simply add as much material as desired, which exceeds the amount that could be introduced from the melt phase. Under this condition we have a supersaturated solid solution that is meta-stable. Annealing the meta-stable system causes the formation of QDs at concentrations that could not be achieved by synthetic chemical routes.

In collaboration with Fisk University, Ion Beam Centre Laboratory at University of Surrey at Guildford Surrey UK, and Institute Rudjer Boskovic, Zagreb Croatia we made formation of Cd, Se and, CdSe quantum dots by successive deposition of 300-600 keV implanted Cd and Se ions. Optical characterization of those quantum dots fabricated by Ion Implantation is also performed.

Ion implantation is used to form quantum dots in fused silica (SiO_2) nanobeads. The nanobeads are commercially available products from a number of vendors; 20 nm to 1 μm size beads with a very narrow sized distribution. In our experiments we used silica spheres that have a diameter of 1.02 microns. The samples prepared by "natural sedimentation", are two-dimensional colloidal crystals consisting of 1.02 micron fused silica spheres deposited on freshly cleaved ruby grade Muscovite mica surface.

While an initial investigation could begin by implanting Si into the silica beads, we decided to implant Cd followed by Se to affect the formation of CdSe quantum dots. The reason for this originates from the fact that Si is easily oxidized to form a SiOx layer. This ubiquitous layer always poses problems in analyzing PL data as well as optical absorption data, whereas CdSe does not suffer from this problem.

The implantation parameters are as follows:

1) Implanted Cd at 450 KeV at ion doses of $1x10^{16}$, $3x10^{16}$, $6x10^{16}$ and $1x10^{17}$ ions cm^2.
2) Implanted Se at 330 KeV at ion doses of $1x10^{16}$, $3x10^{16}$, $6x10^{16}$ and $1x10^{16}$ ions cm^2.

These implantation parameters insured an overlap of the Se and Cd depth profiles. The peak of the profile should be at ~200 nm and the FWHH is also ~200 nm.

The implanted samples were later annealed at 600 C to 700 C for one hour in a 5% hydrogen + 95% nitrogen atmosphere. These are the annealing conditions used previously at Fisk University for growing Se, Cd and CdSe nanocrystals for these ions implanted in the silica windows and should be appropriate for the silica microspheres. These annealing conditions will promote diffusion of the implanted ions, which in turn will lead to nucleation. Once a critical nucleus is formed, the nanocrystals will begin to grow; the ultimate size will depend on the annealing time.

The second stage of experiments will be a repeat of the optical, AFM and RBS characterizations. In particular, the PL will allow to determine if we have been successful at forming the CdSe quantum dots.

The last stage of the experiments will require removing the colloids from the Muscovite mica surface. Intention is to use ultrasonication to remove the colloids. Once the colloids are dispersed by ultrasonication in an ultrapure solvent, a single silica sphere will be isolated in an optical trap and simultaneously the PL will be measured. Based on the PL measurements, it will be possible to determine if any micro cavity effects are present.

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North Carolina Central University

Characterization of Conducting Polymer for Solar Cells Application

A. Holley[1], S. S. Mammana[2], V. Borjanovic[1], B. Vlahovic[1] and J. M. Dutta[1]

[1] Physics Department, of North Carolina Central University
[2] International Technology Center, P.O. Box 13740, Research Triangle Park, NC, 27709-3740, USA

Organic solar cells have been investigated as a low-cost alternative for Photovoltaic cells applications. Polymers are promising for solar cells applications because they are cheap, flexible and can be processed at room temperature. Normally solar cells are made of silicon or gallium arsenide at various configurations aiming high efficiency (reach up to 30%) but require processing with high temperatures and low pressures that is expensive. The efficiency of organic solar cells is still low (2%) but researches of hybrid devices (polymers-nanoparticles) have been presented with promising results. In this work we present electrical characterization of a conductive polymer evaluating its properties for photovoltaic cells applications.

North Carolina Agricultural & Technical State University

Optimizing Manufactured Housing Energy Use

Alaina Jones
North Carolina Agricultural & Technical State University
McLeansville, NC 27301

Researchers in the Center for Energy Research and Technology (CERT) at North Carolina A&T State University are evaluating technologies to improve the energy efficiency of manufactured housing. Two manufactured homes, located at A&T's campus in Greensboro, NC, were used to compare energy use in a side-by-side comparison. One home was built to basic HUD code standard and the other with features expected to produce a home that was 50% more energy efficient. In partnership with Florida Solar Energy Center (FSEC), NC A&T SU began monitoring energy performance in both homes. A comparison of the performance of the units shows a measured energy savings in the test unit of 52% for heating, cooling and DHW energy use. This compares well with predicted savings by the FSEC Energy Gauge program of 57%. This study shows the potential of energy savings in affordable housing.

Center For Energy Research and Technology(CERT)

Harmohindar Singh
North Carolina A&T State University

CERT at North Carolina A & T State University has been involved in teaching, outreach, research and development of energy related issues especially to the 'Built Environment'. It is recognized as a 'Unique Center' by the University of North Carolina system. CERT has been successful in bringing a number of Afro-American minorities in the field of 'Energy'.

My presentation will highlight some of our accomplishments in this area.

Rapid Thermal Processing For Inkjet-Printed Ag Contacts

to Si Solar Cells

Doryne Sunda-Meya*, Tanya Kaydanova**, Maikel Van Hest**, Jeff Alleman**, Dave Ginley**

* North Carolina Central University, Durham, NC 27707

**National Renewable Energy Laboratory, Golden, CO 80401

Rapid thermal processing (RTP) is having a tremendous impact on the study and fabrication of semiconductor device. It has several advantages such as shorter cycle time, low thermal budget, reduced dopant diffusion, reduced contamination and high throughput. RTP qualities are fast ramp-up and cool-down, near uniform temperature across the wafer at all times to avoid damage from thermal stress, and precise trajectory following for process repeatability.

Manufacturing steps require thermal processing, for crystallization of thin films, induction of reactions and phase changes, annealing of defects introduced by energetic processes and the control of stress and topography. The ultimate goal in RTP is to reduce process temperature and duration as much as possible in order to restrict the motion of atoms through atomic diffusion, which tends to change the effective shape of device structures and can cause undesirable side-reactions such as lowered cell efficiency.

RTP has the advantages of good temperature control, ambient atmosphere purity, quick cycle time and process flexibility. This makes it very suitable for the industrial production of highly efficient solar cells.

For this experiment, an RTP set up was completed and tested. The RTP consist of two inches diameter by ten inches long quartz tube surrounded by an array of twelve quartz lamps with water-cooled parabolic reflectors. The reflectors are configured for optimum focus of infrared energy from the lamps on to the sample. The twelve Tungsten halogen bulbs have a moderate temperature up to 3300^o F (1819^o C), and therefore a moderate output power density (1080 kilowatts per square meter). The lamps heat up and cool down instantly in response to power control signals. They radiate 80 percent of the available radiant energy in less than one second after being turned on.

Previously RTP was found highly beneficial for fabrication of polycrystalline Si solar cells [1] especially in the process of the burn-through ohmic contact formation [2]. In this study RTP furnace was used for fabricating solar cells with inkjet-printed silver contacts for the first time.

Silver grids and transfer length method (TLM) patterns were inkjet-printed with metalorganic (MO) silver ink [3] [4] on a silicon substrates with a p-n junction and coated with silicon nitride (Si_3N_4) antireflection (AR) layer and Al-coated back surface as provided by Evergreen Solar. The TLM patterns were annealed using the RTP furnace at various temperatures and for different lengths of time in order to find optimal conditions for the ohmic contact formation between Ag and Si through the AR coating. The effect of the RTP regimes on the contact resistance and the process of the Ag /Si contact formation were studied.

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Efficiency of Solar Flat-Plate Collectors for Durham, NC area

Doryne Sunda-Meya, U. Udoko, A. Barnett, and G. Vlahovic
North Carolina Central University
Durham, NC 27707

The purpose of this study is calculation of efficiency and appropriate use of solar-cell flat plate collectors for Durham, NC area. The systems compared are: the fixed tilt collector, the one-axis tracking flat-plate collector with axis oriented north-south, the two-axis tracking flat-plate collector and the concentrating collector. The total solar radiation they receive will be compared to show the variability of a station's solar resource. For each system the efficiency-cost ratio will be calculated using National Solar Radiation Database (NSRDB). Two of the primary NSRDB stations are located in North Carolina (Cape Hatteras and Raleigh/Durham) and have continuous solar radiation measurements going back to 1952. Solar radiation data provide information on how much of the sun's energy strikes a surface at a location on earth during a particular time period. The total solar radiation received by a flat-plate collector is a combination of direct beam radiation, diffuse (sky) radiation, and radiation reflected from the surface in front of the collector.

RECRYSTALIZATION OF a-Si:H BY LASER BEAMS

Justice McConnell, J. Dutta, and B. Vlahovic
Department of Physics
North Carolina Central University

ABSTRACT:

Several a-Si:H thin films, about 1 μm (micrometer) thick, with different hydrogen concentrations, deposited by hot wire deposition and magnetron sputtering, were crystallized by a cw Ar ion laser of 514.5 nm wavelength, with power density between 0.8 x 106 W/cm^2 and 1.2x106 W//cm$^{2.}$

The process was monitored in situ by Raman spectroscopy (ISA U-1000 spectrometer supplied by water-cooled photomultiplier). The transformation from the amorphous to crystalline phase was detected by the change in the peak position from about 480 cm^{-1} to 505-516 cm^{-1} and the change in the peak shape. The initial crystalline peak intensity increases, peak frequency shifts toward higher wave numbers and their FWHM decreases. After increased exposure time, the process saturates and there are no further changes.

Analyzing the measured Raman spectra, the grain size was estimated by using a semi-empirical formula related to the peak position, while the average temperature of the irradiated volume was determined using the ratio of the Stokes and Anti-stokes intensities of the Raman spectra. Analyzing the surface under the crystalline peak as a function of time, the activation energy of crystallization process was estimated. The dependency of crystals size and activation energy on the initial degree of ordering, hydrogen concentration and power density is discussed.

Residual Stresses and Electronic Properties in multi-layer thin films and quantum dots

K. Wang, B. Vlahovic, V. Suslov, I. Filikian, J. Dutta
Department of Physics
North Carolina Central University
Durham, NC 27707

Multijunctions and Quantum dots have been proposed as promising high efficiency solar cells. They are usually fabricated by growing nanometer sized semiconductor materials on various substrates. The differences in thermoelastic properties between the films, quantum dots and the substrate materials can cause residual stress. The stress will cause defects and micro-structural changes formed in the nano-devices. The electrical, optical, photovoltaic properties, and device lifetime can be detrimentally affected.

In our department, effort has been made in numerical modeling of residual stress and electronic states in both thin films and quantum dots for understanding the relationship of various conditions, such as growth temperature, geometric structure, composition, and their impacts on electronic states and microstructures. Undergraduate students are involved in most stages of the research work in numerical simulations.

Numerical methods, both finite element method and finite difference methods, have been utilized. In residual stress simulations, both lattice mismatch and thermal expansion effects are included. This information can help optimizing growth conditions in order to reduce defects formation inside nano devices. The effects of residual stresses on the electronic and optical properties are also studied numerically. This is accomplished by solving the time-independent Schrödinger equation numerically to obtain the energy states and wave functions. The potential field in the Schrödinger equation also includes the additional potential field induced by the residual strain. The density of states are obtained from the spectrum of the eigenstates in the numerical solutions. The effects of size, strain, composition, and other parameters can be seen directly from the density of states. Numerical simulation results will be discussed and comparison with available data, such as measurements of transport properties will be provided.

North Carolina Central University

Residual Stresses Modeling In Thin Films and Quantum Dots

Derek Woods
Faculty Advisors: Dr. Kai Wang, Dr. J. Duttta and Dr. Branislav Vlahovic,
Department of Physics, North Carolina Central University

Abstract:

Semiconductor thin films and Quantum dots are usually fabricated by growing nanometer sized semiconductor materials on various substrates. Due to the differences in thermoelastic properties between the film and the substrate materials, residual stresses will be generated in the quantum dots. The residual stresses will cause defects to be generated in the devices and consequently affect the electronic and optical properties. The stress includes thermal expansion stress and lattice match stress. Numerical method is applied to model the distribution of the residual stresses. The effects of the size, geometry, composition, and fabrication temperature are investigated. These results provide further information for optimizing growth conditions by studying the effects of each of the factors.

HIGH SURFACE AREA NANOCRYSTALLINE POROUS ELECTRODES FOR HIGH ENERGY DENSITY HYBRID POWER SOURCES

Rambabu Bobba Ph.D.,
Professor of Physics and Project Director
Southern University and A&M College
Baton Rouge, Louisiana-70810

V.Subramanian and Yuriy Malozovsky
Solid State Ionics Laboratory
Southern University and A&M College
Baton Rouge, Louisiana-70813

1) Diletha Kemp, 2) Daryl Sheppard, 3) Marlon Lemond, 4) Amar B. Karki, 5) A. Fathimma, 6) Seon C. Hall, 7) Brandon Jones, 8) Karla Horton, 9) Kenyata Williams, and 10) Kara Broussard
SUBR-PV Associates

At this NREL-HBCU-PV project site, we have been developing low cost, high surface area nanostructured fast ion conducting materials for energy storage, conversion and conservation devices. We have prepared and characterized nanostructured and mesoporous doped and undoped $LiMnO_2$, $LiCoO_2$, $LiNiO_2$, TiO_2, InO_2, SnO_2, WO_2, $LaSrMnO_3$, mesoprous RuO_2, TiO_2, CoO_2, microstructured silver and vanadium silicate glasses, Li_2O-AgO_2, Li_2-SiO_2, Pt, Pt-Ru, Pt-Sn, Pt-Co, Pt-Ru-Os, rare earth dopants in CeO_2, and $LaPrMnO_3$ systems. The optimization of nanoparticle size and electronic and geometric structure of the catalysts and thin film electrodes and electrolytes, the principle performance parameters i.e. electrochemical functionality (electrode interaction rate/extraction kinetics, electrolyte conductivity and mass transport), particle interconnectivity and charge percolation, mechanical stability by means of experimentation and computer simulation or modeling issues, and fabrication of hybrid power source battery/supercapacitor, and solid state microbattery are the key research issues under investigation and are in progress.

In this REAP-2003 conference, our PV associates will present their work in the form of posters along with selected oral presentation.

To begin with the PI Dr. Rambabu Bobba will introduce his research focus to the audience and report the results of the new proposal entitled “ Nanocrystalline and Mesoporous Oxides for Asymetric Supercapacitors for Sonobouys”. Various ruthenium-based compounds were syntheisized using sol gel, non-ionic surfactants templated and pulsed laser deposition (PLD) methods. The synthesized materials were characterized using low angle XRD, XRD, HRTEM, XANES, transport (conductivity), and electrochemical (a.c. impedance, CV, and charge-discharge). The electrochemical characterizations of nanocrystalline and mesoporous bulk and highly oriented ceramic oxide films demonstrated the potential use of ruthenium-based compounds in supercapacitor applications. The nanocrystalline ceramic ruthenates prepared by sol gel route showed promising capacitances, electrochemical stability and are strongly affected by dopants.

Following PIs presentation, the other advisor Dr. Yuriy Malzovski will present the theoretical work on carbon nanotubes and their role in the Hydrogen Storage technologies. The discovery of carbon nanotubes (CNT's) opens a new direction in lithium battery and hydrogen storage research. Recent reports on carbon nanotubes reveal that they have a higher capacity for both lithium and hydrogen storage than graphite. The higher capacity of carbon nanotubes can be explained by both the enhanced effective surface area, to accommodate the intercalation particle (Li or H_2), and different intercalation sites between pseudographic layers, interstatial sites inside or outside the tubes. It is also well known that Li diffusion in graphite is the key factor that determines the rate at which a lithium battery can be charged and discharged. The diffusion of H_2 in graphite can also limit its capacity for storage. The diffusion coefficient of atomic H is expected to be much higher than that for H_2. Many investigators have used the well-known Arrhenius law ($D=D_0\exp(-E_a/T)$) to describe the diffusion phenomena in CNTs. We argue that the above equation is inadequate because of its lack of inclusion of lattice vibrations. In this work we suggest a model for the diffusion of atomic and molecular particles in CNT's that is based on the use of the quantum Boltzmann kinetic equation for an atomic or molecular particle moving in a cylindrical periodic potential. The atomic particle during its motion experiences scattering by the deformational and longitudinal vibrations of the CNT. Using our approximation the quantum kinetic equation reduces to a form similar to the Fokker-Planck equation. We have derived the Arrhennis type diffusion coefficient for a molecular particle in a CNT. The diffusion coefficient depends on the fundamental parameters of the CNT such as the velocity of longitudinal phonons in the CNT, the maximum frequency of the longitudinal phonons, the energy of activation, the effective polarization or deformation radius of the particle, and the coupling constant of the particle to the longitudinal phonons. We show that there is a minimum diameter of the nanotube at which the diffusion coefficient remains large. At smaller diameters we predict a large reduction in the diffusion coefficient. Thus our model predicts that for a nanotube with a diameter less than 1nm the diffusion coefficient for H_2 is an order of magnitude less than for one with a diameter larger than 1nm. For the diffusion of atomic particles like Li and H the reduction in the diffusion coefficient occurs at 0.5 nm. These results indicate that nanotubes with diameters less than 1 nm will have a higher Hydrogen storage capacity than graphite.

In the remaining time allotted to Southern University, we will present the work that is carried out in our laboratory during the year 2002-2003:

Mesoporous SnO_2 as anodes for Li-ion Batteries: Mesoporous tin oxides were successfully prepared using non-ionic surfactants, *Pluronic 123 (P-123)* and *Tetronic 908 (T-908)*. The synthesized materials characterized by HR-TEM and low-**angle XRD** confirmed their mesoporous nature. The X-ray photoelectron spectroscopic (XPS) and wide angle XRD studies revealed that the prepared compounds have casserite type SnO_2 structure. The electrochemical properties of the prepared materials as anodes in lithium batteries showed excellent performance with good reversibility. The first cycle reversible capacity was 1026 mAh/g for the material synthesized using P123. There was a high first cycle irreversible capacity for SnO_2 synthesized using both P123 and T908. There was an increase in the cycling efficiency in subsequent cycles. Cyclic Voltammetry also complemented the cycling results. Electrochemical impedance spectroscopy (EIS) was employed to study the electrode kinetics during the lithium insertion process in the first cycle. There was a decrease in the charge-transfer resistance with respect to the discharge potential. The synthesis, structural and electrochemical properties of the mesoporous tin oxides are correlated and discussed in detail.

Nanocrystalline SnO_2 as anodes for Li-ion Batteries: Nanocrystalline SnO_2 and $Sn_{0.9}In_{0.1}O_2$ were synthesized by a simple soft chemical method. The particle size for $Sn_{0.9}In_{0.1}O_2$ was found to be much lower than the pure SnO_2 as evidenced by HRTEM and XRD studies. The particle size for the $Sn_{0.9}In_{0.1}O_2$ was 7 nm and for SnO2 it was 40 nm for the materials synthesized at 650 ^oC. Electrochemical performance of both SnO_2 and $Sn_{0.9}In_{0.1}O_2$ showed excellent reversibility for Li-ions with the doped system showing better cycling performance than the undoped SnO_2. The main reason for the improved cycling performance for the doped system being its extremely fine nanoparticles. Further work to understand the effect of calcination temperature and cycling rates on the electrochemical properties of the undoped and doped systems are underway.

Mesoporous Anhydrous RuO_2 as Supercapacitor Electrode: Anhydrous mesoporous Ruthenium oxide was synthesized by a simple non-ionic surfactant templating method using Pluronic 123 and tested as active electrode material for an electrochemical supercapacitor. XRD studies showed the formation anhydrous phase of RuO_2 for the material calcined at 400 ^oC/5h. Cyclic voltammetric studies were performed to estimate the capacitance of the synthesized material. There has been a strong dependence of the capacitance of the material on the voltage scan rates. The capacitance values showed a linear decrease with respect to the increase in the scan rate. The origin of capacitance was found to be from the pseudocapacitance in the RuO_2 material and not from any double layer contribution as evidenced by the CV studies at different molar concentrations of the electrolyte. The capacitance for anhydrous RuO_2 was found to be 58 F/g. The synthesis, structural and electrochemical properties of the mesoporous RuO_2 are discussed in detail.

Nanocrystalline Bulk Powders of Ni rich $LiNiCoO_2$ for All Solid State Li-ion Microbattery: A triethanolamine:sucrose (TEA:Sucrose) assisted complexing method has been employed to synthesize $LiNi_{0.5}Co_{0.5}O_2$ system which is considered to be a potential candidate as cathode material for lithium ion batteries. The TEA:Sucrose ratio has been varied and the change in the structural and electrochemical properties of the systems have been studied and correlated. The prepared materials were characterized using XRD, SEM and electrochemical charge-discharge. The particle size of these materials were in the sub-micron range of ~ 300 to 350 nm. $LiNi_{0.5}Co_{0.5}O_2$ synthesized with a TEA:Sucrose ratio 1:8 exhibited improved electrochemical performance which was well complemented by the structural studies. The 1st and the 10th discharge capacities were 152 and 144 mAh/g, respectively. The structural and the electrochemical properties of the materials were correlated and discussed in detail.

Nanocrystalline Thin Films of Co rich $LiCoNiO_2$ for Li-ion Microbattery: Highly oriented nanostructured thin films of $LiCo_{1-x}Ni_xO_2$ ($0 \le x \le 0.3$) were prepared by pulsed laser (KrF, λ=248 nm) deposition technique under in-situ conditions. Powder x-ray diffraction (XRD) and selected area electron diffraction (SAED) studies show that that the films grown on (100) $LaAlO_3$ exhibits the desirable (104) orientation for probable higher Li-ion diffusion. Whereas the films on (0001) sapphire and polycrystalline alumina are predominantly c-axis oriented with Co-O layers normal to the direction of Li-ion diffusion. Deposition parameters such as substrate temperature, oxygen partial pressure, laser pulse energy, repetition rate etc. are varied to realize the growth of high quality thin films. Morphology of the films investigated by Atomic Force Microscopy (AFM) and Transmission electron microscopy (TEM) reveals with the average grain size in the range of 100 – 150 nm. SAED studies show that the films on (0001) sapphire exhibits twins and superstructures while the films on (100) $LaAlO_3$ do not.

Nanocrystalline Pt, Pt-Ru, Pt-Ru-Os Catalysts for Fuel Cells: We report the synthesis and spectro-electrochemical characterization of platinum black and carbon-supported platinum with varying amounts of carbon-support for fuel cell applications. The structural aspects of the carbon supported Pt-catalysts were studied using XRD, HRTEM and XPS. The broad XRD peaks indicated the presence of nano particles of Pt, which was well complemented by the HRTEM studies. . The valence states and the variation of the binding energy with respect to the particle size of the electrocatalysts were elucidated by XPS studies. The metal-support interaction in these carbon-platinum electrocatalyst and their influence on the oxidation of CO and methanol are also reported. The nanosturucture nature of the catalysts and its influence on the methanol oxidation are related and discussed.

Solar Photovoltaic Production

Kara Broussard
National Center for Photovoltaics
Golden, Colorado

Southern University and A&M College

One of the fastest growing topics and research of this technological age is the "hydrogen market". Since on the daily news first thing that is heard with weather is the daily health advisory (smog level). The "freedom car" is becoming of interest to U.S. government since our energy and fuel demands are on the rise, hydrogen has shifted to the main focus of our future energy supply. Yet, there are question of its economical applications, supply and demand, location, technical and storage viability for essentially the most important energy resource in the production of renewable energy. Solar (primarily photovoltaics (PV)) is a key component on the road of renewable energy future and this study probes the basis for an economically sound hydrogen production used to power everyday necessities with zero-emission and the only byproduct, water. This technology can no longer to be considered the fiction of Jules Verne in *The Mysterious Island* of 1874.

Numerous methods of solar hydrogen production were evaluated; this consist of photolysis the direct method for producing hydrogen from water using solar cells with different types of chemical species and electrolysis the indirect separation of water components by means of an electrolyzer powered by photovoltaic (solar) modules. (The former is already available commercially, and the latter is still in the research stages. This paper reviews past and current work in each of the approaches). Discussed and compared are the outstretching advantages and technical degrees. The economical competitiveness of a hydrogen future is examined in reference to the existing polluting infrastructure (EIA and Hydrogen are a few of the several sources furnished). Even hydrogen power plants can replace existing plants and cars can be retrofitted for the use of hydrogen. Hydrogen is broadening our energy choices and rivaling the fossil fuel market that is a reason why the U.S. Photovoltaic Industry and European Solar Energy Industry Roadmaps are being evaluated to predict when the electricity generation produced from photovoltaics will be profitable for hydrogen based production. Even though these Roadmaps are 20 years in the foreseeable future, experience and learning curves offer a projected price foundation for photovoltaics (solar) technology. Yet, there are advancements that are possible alternating factors in the learning curve process (for lower electricity generation provided by a cost efficient solar hydrogen production on the basis of past experiences). A potential factor being presented for photovoltaics into a hydrogen-based distributive market is the development of "distributive technologies" which include preeminent generations of PV such as thin films, nanotechnology, plastics, etc. For example, researchers are investigating nanotubes for the storage of hydrogen since it occupies little space and is relatively safer than in canisters or drums.

Two distinct approaches/concepts for hydrogen production are assessed in terms of solar technologies: (1) central (large-scale utility level) station using large PV fields or concentrators; (2) distributed generation (both single residence and communities, for example, solar hydrogen parks/villages). The pros and cons for each are weighed. A suitable aspect for the future would be a park or building equipped with mass solar hydrogen production and distribution. Maybe in the distant future, a cogeneration process can be strapped on to this technology to reuse the other byproduct heat.

This work includes: (1) literature searches, (2) demonstrations of solar hydrogen production methods; (3) economic evaluations of the materials, devices, and electricity requirements; and (4) modeling and graphical representations of the proposed "production and distribution" systems.

Community Energy Distribution: Current Power and Lighting

Julie Bush
PV Research Associate
Texas Southern University

Abstract: In this research we are focused on a particular area of the Houston, TX community, that is the area surrounded by, at the West boundary: Almeda / Crawford Streets; at the North boundary: Gulf freeway; at the East boundary: Spur 5; finally, at the Southern boundary: Old Spanish Trail. In this paper we discuss the community power distribution that flows form the main power supplies of the Greater Houston Area to this specific location. That includes both the power and the lighting systems. In addition, we looked at several distributions of this energy in different divisions: public, commercial, industrial, private.

Texas Southern University

Renewable Energy Technology Guide for Urban Applications

REAP Student PV Associates
Texas Southern University
College of Science and Technology

Abstract: Renewable Energy / Sustainable Energy Technology are methodologies that extract from natural resources (such as the sun, wind, biomass, and geothermal), energies and converting these energies, usually heat, into electrical power or fuel. Such methodologies have application in all communities rural, suburban, and urban. The research of this study focuses on the application of these technologies in urban communities. When considering using renewable / sustainable energy forms in urban communities a number of factors must be addressed. The biggest of these can be, " is the cure worst than the disease"? An ugly forest of windmills or a large bank of solar panels in crowed urban communities. These are issues that must be considered among others. The idea of renewable / sustainable energy are not easily put into practice in urban communities. The general thought is that the expense is too great for the benefit gained. The work of this research has addressed these issues for urban communities and has attempted to establish some guidelines for using renewable / sustainable form in urban communities. The REAP Student Associates at Texas Southern University have used the Urban Community within a 1 to 2 mile radius of the University as a target community to study and develop guide lines for the application of renewable/sustainable technology.

Community Limitation on Renewable Energy Forms

Tehron Jones
Central State University / Texas Southern University

Abstract:

Renewable energy refers to energy resources that occur naturally and repeatedly in the environment and can be harnessed for human benefit. Examples of renewable energy systems include solar, wind, and geothermal energy (getting energy from the heat in the earth). We also get renewable energy from trees and plants, rivers, and even garbage. We hope to bring these methods to the surrounding areas of Texas Southern University in Houston, TX. In finding how we could help this community with implementing these programs, we have to establish what would be the deed restrictions placed in this area and what would be the allowable forms of renewable energy we could use in the areas. Also we would need to research the current uses of renewable energy in the community, so that we could implement better projects and also get a basic understanding of what this community needs in correlation with renewable energy.

Urban Renewable Energy in addressing The International Energy Conservation Code, as well as, Compliance Analysis and Verification

Nkenge Mtendaji
Texas Southern University

Abstract:

This presentation provided information on the study of the International Energy Conservation Code as well as its compliance analysis and verification for renewable energy use in an Urban Community. The study examines the code from four perspectives: Its universal, national, state, and local applications. This study further explains the IECC and outlines an analysis and compliance procedure with specific emphasis on renewable / sustainable energy forms.

Texas Southern University

Guidelines for Applying Renewable in Urban Communities

Stern Sabaroche
Texas Southern University

Abstract:

This presentation provides the results of the research activity conducted at TSU. These guides are in conclusive but focuses on Public, commercial, industrial, and private applications of renewable / sustainable. Attempts were made to identify for urban communities the best and most effective uses of renewable energy technologies.

Texas Southern University

The Urban Community

Tony Prince
Texas Southern University

Abstract:

Solar energy is electricity that is directly produced from sunlight. Solar energy is one primary form of renewable energy to most home and building owners. New structures, designed to use solar energy, are usually built to be much more “energy efficient”. The two major categories of solar energy are Passive and Active. The use of solar energy as a power source imposes no fuel requirements to be fulfilled. Solar systems cause no pollution. They live a long life and have a high reliability together with a very low maintenance. The use of solar systems provides low running costs and requires no supervision. Here at Texas Southern University, College of Science and Technology we as Photovoltaic Research Associates are currently doing research in order to put together a Renewable Energy Technology Guide for Urban Applications. We also research the amount of solar energy usage, as well as, the basic power and lighting in public, commercial, industrial and private areas. In order for us to put this guide together we needed to research the current uses of renewable energy in urban communities.

University of Central Florida

Opportunities for Research and Study at the Florida Solar Energy Center

Dr. Carol Emrich

Florida Solar Energy Center (FSEC) is research institute of the University of Central Florida (UCF), and functions as the state's energy research, training and certification center. It is located in Florida's Space Coast on 20-acres of UCF's Cocoa Campus, 35 miles east of Orlando. FSEC is the largest and most active state-supported renewable energy and energy efficiency research, training, testing and certification institute in the United States.

FSEC's mission is to research and develop energy technologies that enhance Florida's economy and environment, and to educate the public, students and practitioners on the results of these efforts. The Center has gained international recognition for its wide range of accomplishments in these areas. The following is a brief overview of ongoing activities and programs at FSEC.

Photovoltaic systems, applications and cells - The PV program is one of FSEC's largest activities and most diverse. It covers every aspect from basic materials and cell research to systems and applications for disaster relief. Other critical program areas include research on batteries and charge controllers, module durability, building-integrated photovoltaics, area lighting systems, technical assistance, standards development and PV applied education and training coupled with distance learning. Recently, efforts have been broadened to include distributed generation.

Solar thermal systems - The FSEC Solar Water Heating (SWH) program continues to lead the nation and is poised to become international. The SWH certification program began under mandate of the Florida Legislature in 1979. Eventually, the Florida and California programs were merged and the national Solar Rating and Certification Program (SRCC), which FSEC currently manages, was created. FSEC's new systems laboratory is now in full-scale operation and houses the nation's only solar thermal simulator. These activities have helped make Florida the nation's leader in the use of solar energy for both pool and water heating.

Energy efficiency and building science - FSEC conducts significant field and laboratory monitoring and analytical research for a variety of sponsors in support of its energy efficiency and building science programs. The research team leading these programs also has significant software development expertise. Detailed and user-friendly software has been developed at FSEC to simulate complex phenomena like combined heat and moisture transport and uncontrolled air flow interactions in buildings, and to determine code compliance and energy ratings. The Center's Building Research Division personnel have extensive experience conducting building energy simulation modeling and analysis projects. Through the Florida Energy Gauge program (sponsored by the Florida Department of Community Affairs), the Energy Star New Homes program (sponsored by the U.S. Environmental Protection Agency) and the Energy-Efficient Industrialized Housing Program (sponsored by the U.S. Department of Energy), FSEC has also developed a comprehensive capability to assist builders and home owners in constructing high-quality, energy-efficient homes. FSEC regularly provides design guidance, conducts diagnostic tests in the field to assure quality, and performs long-term monitoring to document the benefits for clients from large utility corporations to Habitat for Humanity

Indoor air quality - Indoor air quality (IAQ) is a major focus of FSEC Building Science research. We believe that buildings can be designed, built and commissioned to minimize allergens and toxins inside. This should reduce allergy-related illnesses and provide significant tax-dollar savings. Understanding uncontrolled airflow in buildings, which is air movement that is unintended and of unknown or undesirable origin, is key to improving IAQ. FSEC is one of the nation's leaders in this. While testing more than 600 residences and 95 commercial buildings, our researchers have uncovered many cases of poor indoor air quality in homes, restaurants and offices.

Advanced HVAC systems - FSEC has investigated the use of heat pipes in conventional air conditioners to reduce humidity in an aerospace cable manufacturing facility. Results show a 20%-30% reduction in annual electrical energy consumption and 40% demand savings. Detailed laboratory testing of desiccant-enhanced air conditioning has been conducted. Results show improved dehumidification performance over conventional systems, with minimal impact on system capacity and efficiency.

Hydrogen energy from renewable resources - In 1997, the U.S. Department of Energy named FSEC a Center of Excellence in Research and Education for Hydrogen. The new Center of Excellence will expand FSEC's basic R&D work to include visiting researchers and the establishment of a hydrogen-usage corridor in Florida. The goal of FSEC's long-term, high-risk hydrogen research is to develop a dual-bed reactor process, to photocatalytically split water into hydrogen and oxygen, and to chemically synthesize an electrolytic membrane for high-temperature electrolysis.

Pollutant detoxification - The application of ultraviolet light and photocatalytic semi-conductors to purify air contaminated with hazardous chemicals is a major program in FSEC's photoprocesses area. This highly technical chemical-based research is helping the U.S. Navy, at Indian Head, Maryland, deal with volatile organic compounds -- air pollutants emitted from its defense operations. This groundbreaking research has developed a mechanism scale prototype that is currently being tested at FSEC. The project goal is to design a full-scale detoxification reactor for defense and civilian use throughout the United States.

Education and training - As an institute of the University of Central Florida, FSEC has always had education and training as one of its top priorities. Workshop topics include, but are not limited to, solar water heating, photovoltaics, energy-efficient building design, distributed generation, disaster relief, and alternative fuel vehicles. FSEC has also established a distance education/videoconferencing classroom with the capability to effectively implement both satellite-based and terrestrially networked distance education programs.

Research at FSEC is based on experimental data from highly instrumented laboratories and field test sites. Detailed analytical models are developed and validated with the experimental data. Systems analysis, cost-benefit analysis and technology transfer follow research that demonstrates technology feasibility. Results are published and widely disseminated. For more detailed information, please visit our website at www.fsec.ucf.edu.

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Contacts

Fannie Posey Eddy
National Center for Photovoltaics
National Renewable Energy Laboratory
1617 Cole Boulevard, MS-3214
Golden, Colorado 80401
Phone: (303) 384-6773
Email: fannie_eddy@nrel.gov

Dr. G. Tamizh-Mani
Arizona State University East
Williams Campus
7349 East Unity Avenue
Mesa, Arizona 85212
Phone: (480) 727-1241
Fax: (480) 727-1223
Email: manit@asu.edu

Bob McConnell
National Center for Photovoltaics
National Renewable Energy Laboratory
1617 Cole Boulevard, MS-3221
Golden, Colorado 80401
Phone: (303) 384-6419
Email: bob_mcconnell@nrel.gov

Syl Morgan-Smith
Communications and Public Affairs
National Renewable Energy Laboratory
1617 Cole Boulevard, MS-1733
Golden, Colorado 80401
Phone: (303) 384-3001
Email: syl_morgan-smith@nrel.gov

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